Hazard Identification and Vulnerability Assessment (HIVA)

An Assessment of Hazards and Risks to the People, Economy, Environment, and Property of Washington State

Washington State Military Department
Emergency Management Division

September 2009

Forward

The Washington Military Department's Emergency Management Division (EMD) mission is to minimize the impact of emergencies and disasters on the people, economy, environment, and property of Washington State.

A major responsibility for EMD is to maintain a State Hazard Identification and Vulnerability Assessment (HIVA) in compliance with the Revised Code of Washington (RCW). This latest edition provides current research and information about those hazards to which the State of Washington is most vulnerable. I encourage all readers to use this document as a resource to understanding the hazards they face.

Our process involved local emergency managers in establishing criteria to select those hazards that must be addressed at the state level. Local jurisdictions will be able use this document to assist them in the development of their own HIVA. Additional uniquely local hazards will be added to the development of each local jurisdiction's HIVA. The State Comprehensive Emergency Management Plan is based on the HIVA to ensure we address all potential risks.

Emergency Management has the task of planning, preparing, responding and recovering from natural and man-made emergencies and disasters. The better we plan and prepare the less the impact from the disasters and incidents we have to respond to and recover from. This document is the first step in an iterative processes needed to build a "disaster resistant Washington."

Sincerely,

Timothy J. Lowenberg, Major General
The Adjutant General
Director, Washington Military Department

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Introduction

The Washington State Hazard Identification and Vulnerability Assessment (HIVA) assess geographically fixed, biological, geological, meteorological, and man-made hazards that exist in Washington State. Assessment is the first step in the emergency management planning process. Once identified, mitigation and preparation for these hazards can commence. In the event that one of these hazards takes place, the final steps of the planning process, response and recovery will come into effect. The hazards identified in this document have the potential of becoming emergencies or disasters that can adversely and irreversibly affect the people, economy, environment, and property of the state of Washington.

Vulnerability assessments are one of the tools emergency managers utilize to help determine the risk, vulnerability, and impact a particular disaster could have in their area of responsibility, be it a county, city, university, etc. Emergency managers with good vulnerability assessments can effectively organize resources and develop comprehensive emergency management plans to minimize the impact of disasters and emergencies.

This HIVA contains information gathered from public sources in addition to federal, state, and local government sources. The Washington State Military Department's Emergency Management Division (EMD) publishes this document. Address recommendations for improvements or comments concerning this document to:

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Acknowledgements

Many people contributed to the creation and review of this document. Without their support, this document would not have been possible. The following people contributed or supported the process of developing this document:

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We also greatly appreciate the many hazard experts who reviewed and contributed to the hazard profiles:

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Purpose

The primary purpose of this document is to meet the requirements of the Revised Code of Washington (RCW) 38.52.030(3) by providing the hazard identification and analysis to support the *Comprehensive Emergency Management Plan* (CEMP). Additionally, this document should be the impetus for the *State Hazard Mitigation Plan* as well as local hazard plans.

> RCW 38.52.030(3)
> "The director shall develop and maintain a comprehensive, all-hazard emergency plan for the state which shall include an analysis of the natural, technological, or human caused hazards which could affect the state of Washington, and shall include the procedures to be used during emergencies for coordinating local resources, as necessary, and the resources of all state agencies, departments, commissions, and boards. The comprehensive emergency management plan shall direct the department in times of state emergency to administer and manage the state's emergency operations center. This will include representation from all appropriate state agencies and be available as a single point of contact for the authorizing of state resources or actions, including emergency permits. The comprehensive emergency management plan must specify the use of the incident command system for multi-agency/multi-jurisdictional operations. The comprehensive, all-hazard emergency plan authorized under this subsection may not include preparation for emergency evacuation or relocation of residents in anticipation of nuclear attack. This plan shall be known as the comprehensive emergency management plan."[1]

Executive Summary

The Hazard Identification and Vulnerability Assessment complies with the Emergency Management Accreditation Program (EMAP) Standard 4.3.1 by identifying and analyzing the technological and natural hazards that are present and pose a threat to the people, economy, environment, and property of Washington.

EMAP Standard 4.3.1, Sept. 2007
The program shall identify the natural and human-caused hazards that potentially affect the jurisdiction using a broad range of sources. The program shall assess the risk and vulnerability of people, property, the environment and the program/entity operations from these hazards.

To determine the hazards to include in the HIVA, analysts considered each of Washington's local jurisdiction HIVA documents along with the other prominent state or nationwide hazards. After setting a minimum threshold for inclusion for each of the four categories of people, economy, environment, and property, this list of hazards was narrowed down to the eighteen hazards included in the HIVA.

Analysts conducted extensive research into the history and vulnerability for each hazard and included a risk assessment using subject matter experts, publications, and the best-known science and technology on the subject. Based on this research, analysts generated a risk table for each hazard section with a best-known estimate of the hazard's potential effects. In addition, the risk assessment included the potential impacts each hazard poses to the people, economy, environment, and property of the state. Also included with each hazard section are the possible or known impacts that climate change may pose to the risk of such event or the severity or frequency of the occurrence of the hazard.

Technological Hazards

- Technological hazards included in the HIVA are pipelines, dam failure, incident-chemical, incident-radiological, Umatilla Chemical Depot, Columbia Generating Station, and terrorism (including cyberterrorism and weapons of mass destruction).
- All of the technological hazards included in the document have low to minimal risk but have potential for a high degree of impact should one of these events occur.
- Research material to determine risk and vulnerability of these hazards was difficult to find and relied on subject matter experts when available.

Natural Hazards

- Natural hazards included in the HIVA are: avalanche, drought, earthquakes, epidemic/pandemic, urban fire, wildland fire, floods, infestation, landslide, tsunami, severe storms, and volcanoes (including ash fall and lahar)
- These natural hazards occur more frequent then the technological hazards and have a history of causing a high degree of impact to the people, economy, environment, and property of the State.
- Research material including scientific publications to determine risk and vulnerability are readily available for most natural hazards. We relied upon subject matter experts to provide guidance and clarification during the writing and editing process.

The natural and technological hazards included in the HIVA are those hazards considered having the highest degree of impact or frequency of occurrence that adversely affect the people, economy, environment, and property of Washington. While mitigation and personal preparedness efforts can lessen the impact and severity of natural and technological hazards, the risk and vulnerability cannot be eliminated.

Although the risk of these hazards cannot be completely eliminated, with mitigation and preparedness efforts a good assessment of risk and vulnerability can guide emergency managers toward those hazards that are in need of mitigation and preparedness plans. With these plans, the state and local jurisdictions can better prepare for and respond to disasters, limiting their impact to the people, economy, environment, and property of Washington.

Risk Matrix

The following criterion generated a risk matrix of the hazards that are included in the hazard assessments section of this document.

Frequency of Occurrence	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
(A) Occurs Annually	1A	2A	3A	4A
(B) 1-10 year Occurrence	1B	2B	3B	4B
(C) 10-50 year Occurrence	1C	2C	3C	4C
(D) >50 year Occurrence	1D	2D	3D	4D

(Risk table in the HIVA identifies one or more of these impacts; for a combination of impacts from within different categories a judgment was made to assess which of these categories that the event would fall into)

Hazard Category Definitions

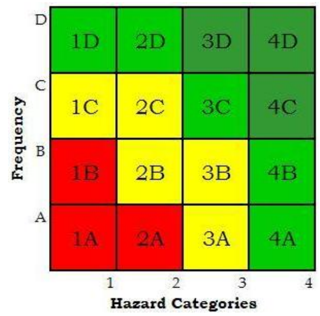
Catastrophic: People dead or injured is greater than 10,000; Economic impact is greater than 2% of State GDP; Environmental impact is greater than 15% of a single habitat or species; Property Damage is greater than $500 million dollars.

Critical: People dead or injured equals 1,000 to 10,000; Economic impact equals 1 to 2% of State GDP; Environmental impact is between 10 -15% of a single habitat or species; Property damage is $100 to $500 million dollars.

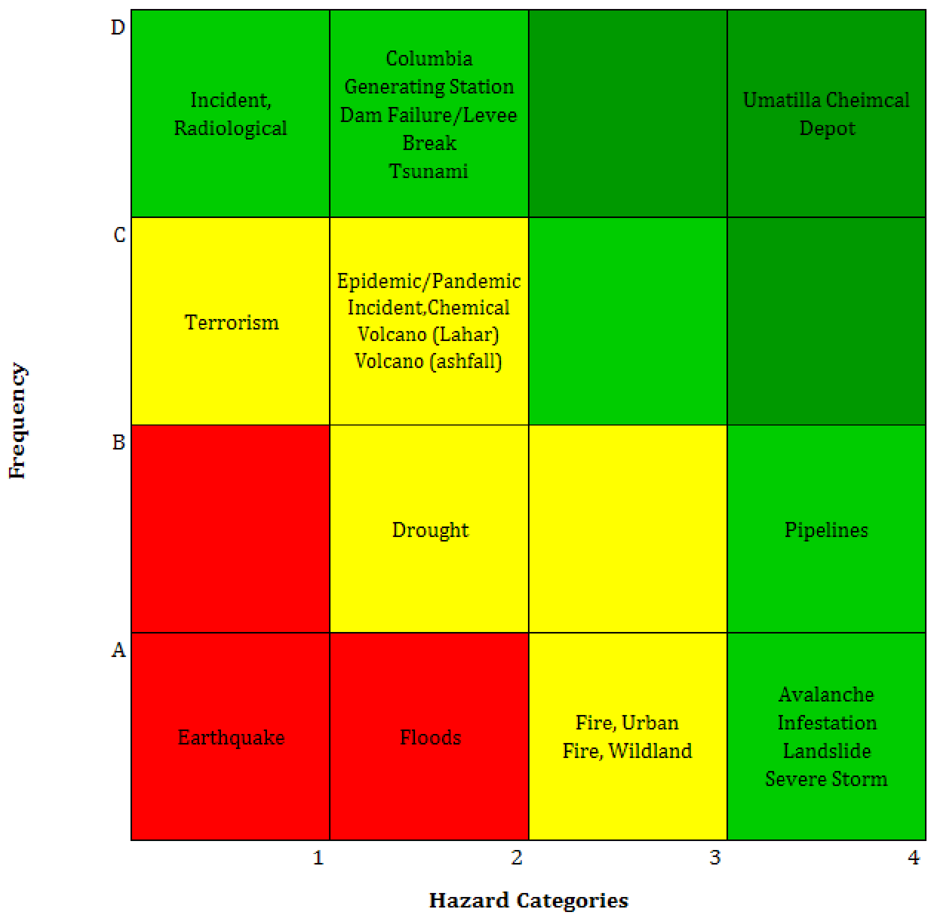
Marginal: People dead or injured is 500- 1,000 people; Economic impact equals 0.5% to 1.0% of State GDP, Environmental impact is between 5- 10% of a single habitat or species; Property damage is between $50-$100 million dollars

Negligible: People dead or injured totals less than 500; Economic impact is 0.1% - 0.5% of State GDP; Environmental impact is less than 5% of a single habitat or species; Property damage is less than $50 million dollars

Risk Classification	Risk Criteria
1A, 1B, 1C, 2A, 2B	Risk mitigation required to reduce risk to level C or D
2C, 3A, 3B	Risk mitigation required to reduce risk to level C or D
1D, 2D, 3C, 4A, 4B	Mitigation to reduce risk to level D is optional
3D, 4C, 4D	No further risk mitigation is required



HIVA Hazard Category Risk Identification



Preparation Process

A review team consisting of volunteers from the cadre of State Agency Liaisons (SAL), technical or scientific experts, and local emergency managers provided input and comments to the process. Using Federal Emergency Management (FEMA) publication *386-2 Understanding Your Risks* as a guide, the Emergency Management Division (EMD) identified all the hazards within local plans; then considered other hazards. A comprehensive list of hazards affecting Washington was created and criteria were suggested for selecting the hazards to be assessed. This information was provided to the review team for comment. For each selected hazard, a detailed assessment was then accomplished and each of those hazards was provided to the Review Team. When this document was complete, an Executive Summary was written and a final draft was commented on by the review team. The document then went to EMD unit managers, the State Emergency Management Director and finally to The Adjutant General for final approval and publishing.

History of Washington Presidential Declarations

When an incident becomes beyond the capability of the local jurisdiction to handle and requires assistance by the federal government, the Governor asks the President to make a major disaster declaration. Definition of a major disaster:

> "Any natural catastrophe (including any hurricane, tornado, storm, high water, wind-driven water, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, or drought), or, regardless of cause, any fire, flood, or explosion, in any part of the U.S. which in the determination of the President causes damage of sufficient severity and magnitude to warrant major disaster assistance under this Act to supplement the efforts and available resources of States, local governments, and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby."[2]

Major Disaster Declarations

Year	Date	Disaster Types	Federal Disaster #
2009	2-Mar	Severe Winter Storm and Record and Near Record Snow	1825
2009	30-Jan	Severe Winter Storm, Landslides, Mudslides, and Flooding	1817
2007	8-Dec	Severe Storms, Flooding, Landslides, and Mudslides	1734
2007	14-Feb	Severe Winter Storm, Landslides, and Mudslides	1682
2006	12-Dec	Severe Storms, Flooding, Landslides, and Mudslides	1671
2006	17-May	Severe Storms, Flooding, Tidal Surge, Landslides, and Mudslides	1641
2003	7-Nov	Severe Storms and Flooding	1499
2001	1-Mar	Earthquake	1361
1998	16-Oct	Landslide in the City of Kelso	1255
1998	5-Oct	Flooding	1252
1997	21-Jul	Snowmelt and Flooding	1182
1997	2-Apr	Severe Storms, Flooding, Landslides, and Mudslides	1172
1997	17-Jan	Severe Winter Storms and Flooding	1159
1997	7-Jan	Ice and Snow Storms	1152
1996	9-Feb	Severe Storms and Flooding	1100
1996	3-Jan	Storms, High Winds, and Flooding	1079
1994	2-Aug	El Niño Effects (Salmon Industry)	1037
1993	4-Mar	Severe Storm and High winds	981
1991	13-Nov	Fires	922
1991	8-Mar	High Tides and Severe Storm	896
1990	26-Nov	Flooding and Severe Storm	883
1990	18-Jan	Flooding and Severe Storm	852
1989	14-Apr	Heavy Rains, Flooding, and Mudslides	822
1986	15-Dec	Severe Storms and Flooding	784
1986	26-Jul	Severe Storms and Flooding	769
1986	19-Mar	Heavy Rains, Flooding, and Landslides	762
1986	15-Feb	Severe Storms and Flooding	757
1983	27-Jan	Severe Storms, High Tides, and Flooding	676
1980	21-May	Volcanic Eruption: Mount St. Helens	623
1979	31-Dec	Storms, High Tides, Mudslides, and Flooding	612
1977	10-Dec	Severe Storms, Mudslides, and Flooding	545
1975	13-Dec	Severe Storms and Flooding	492
1974	25-Jan	Severe Storms, Snowmelt, and Flooding	414
1972	10-Jun	Severe Storms and Flooding	334
1972	24-Mar	Heavy Rains and Flooding	328
1972	1-Feb	Severe Storms and Flooding	322
1971	9-Feb	Heavy Rains, Snowmelt, and Flooding	300
1965	11-May	Earthquake	196
1964	29-Dec	Heavy Rains and Flooding	185
1963	2-Mar	Floods	146
1962	20-Oct	Severe Storms	137
1957	6-Mar	Floods	70
1956	25-Feb	Flood	50

Fig. A Major Disaster Declarations See Appendix B

Hazard Identification

County/City Plans

Current plans from each county and participating city were reviewed and their identified hazards listed in Appendix A. The list was reviewed by EMD staff members and grouped by similar hazards. Additional hazards were identified and then the criteria was applied to determine which of the total hazards were to be included in this document.

Criteria

It is important to select hazards, which cause the greatest impact to the State of Washington. The selection process utilized impact thresholds as indicated below. A hazard that met two or more thresholds is included in the assessment section.

Frequency	Annual Occurrence
People	1,000 or more lives lost
Economy	1% State Gross Domestic Product (GDP) loss ~ $ 3 billion
Environment	10% or more loss of a single species or habitat
Property	$100 million or more in loss damages

Risk Level

Using the thresholds above, an arbitrary scale was created to quickly present a visualization of the potential losses for each hazard. The table uses different colors to distinguish criterion. It indicates four levels. The first level is equal to the minimum criteria. The fourth level equals the worst-case scenario. The second and third levels provide intermediate losses.

Frequency	50+ yrs	10-15 yrs	1-10 yrs	Annually
People	1,000	1-10,000	10-50,000	50,000+
Economy	1% GDP	1-2% GDP	2-3% GDP	3%+ GDP
Environment	10%	10-15%	15-20%	20%+
Property	$100M	$100-500M	$500M-1B	$1B+

Symbolization

When displaying a hazard incident on a map we use standard symbols as agreed on by the Federal Geographic Data Committee - Homeland Security Working Group Symbology Reference whenever possible. If a standard symbol is unavailable, we have adopted or created one and provided the reference here.

Fig. B Federal Geographic Data Committee's Homeland Security Working Group's Symbology Reference

Selection

The hazards selected below were identified using the risk level thresholds:

- Avalanche – Frequency and People
- Columbia Generating Station – People, Economy, Environment, and Property
- Dam Failure/Levee Break – Frequency, People, Economy, and Property
- Drought – Frequency, Economy, and Property
- Earthquake – Frequency, People, Economy, and Property
- Epidemic/Pandemic – Frequency, People, and Economy
- Urban Fire – Frequency and Property
- Wildland Fire – Frequency and Property
- Flood – Frequency, People, Economy, and Property
- Incident, Chemical – Frequency and People
- Incident, Radiological –Frequency, People, Economy, and Property
- Infestation – Frequency, Economy, and Property
- Landslide – Frequency and Property
- Pipelines – Frequency, Economy, and Property
- Severe Storm – Frequency and Property
- Terrorism (inc. Cyber & WMD) – Frequency, People, Economy, and Property
- Tsunami – Frequency, People, Economy, and Property
- Umatilla Chemical Depot – Frequency, People, and Economy
- Volcano (including Ash Fall & Lahar) – Frequency, People, Economy, and Property

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Hazard Assessments

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Avalanche

Frequency	Annually
People	1,000
Economy	
Environment	
Property	

Risk Level

- Frequency – Avalanches occur annually in Washington.
- People – National and international statistics show that there is the potential for significant loss of life from an avalanche.
- Economy – An incident is unlikely to cause the loss of 1% of the State GDP.
- Environment – An incident is unlikely to cause the loss of 10% of a single species or habitat.
- Property – An incident is unlikely to cause $100 million in damage.

Hazard Area Map

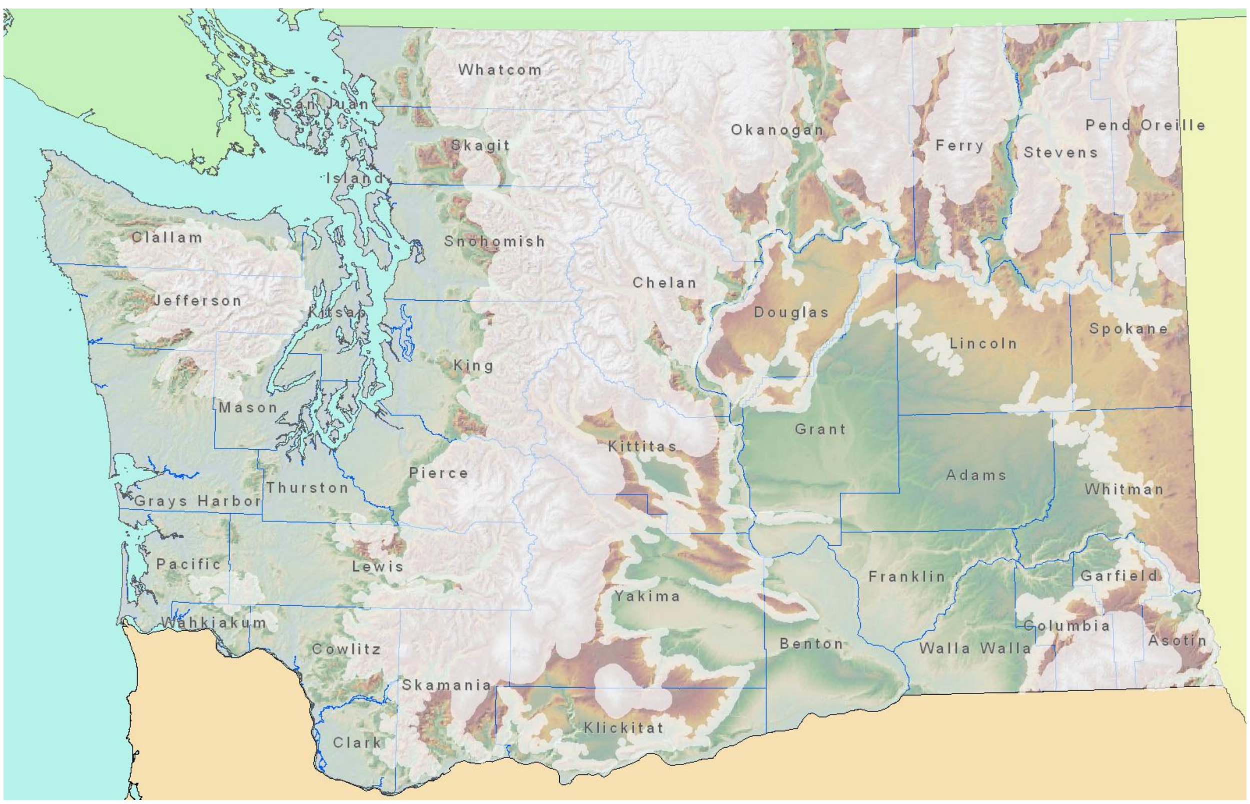

Figure 1-1 Washington State Avalanche Hazard Areas

White areas on the map in Figure 1-1 indicate that those areas are at least 2,000 feet in elevation and most likely to be prone to avalanches. It should be noted that avalanches can and do occur outside of these areas during unusual conditions.

Definition

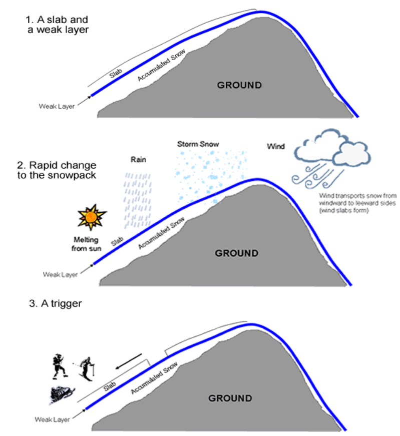

Figure 1-2 Ingredients for a Slab Avalanche

An avalanche is an often-rapid downhill motion of the snow pack or portion of the snow pack. Some wet snow or slush-flow avalanches may travel quite slowly. This motion may be natural or artificially induced, and controlled or uncontrolled in terms of time, place, and severity. Avalanches are often classified according to a variety of factors. These include but are not limited to: 1) time and date of slide release; 2) location; 3) elevation and aspect; 4) type – loose or slab – hard, soft or wet; 4) size –several different size classification schemes exist in North America; 5) content of liquid water in the deposition – dry, moist or wet; 6) type of avalanche trigger – artificial or natural; 7) position and depth of sliding surface – new snow, old snow, or ground; 8) crown width, vertical fall distance; and 9) average and maximum depth of deposited snow. [3] As illustrated in Figure 1-2.

History

Washington is home to four mountain ranges: the Cascade Range, the Olympic Mountains, the Blue Mountains, and the Selkirk Mountains. The western slopes of the Cascade Range and the Olympic Mountains receive, in a given year, more snow than the Blue Mountains and Selkirk Mountains, due to their orientation to Pacific storms that bring rain and snow to much of western Washington. The avalanche season for the state typically begins in early-mid November and extends through the winter and into late spring or early summer. The potential for avalanches exists in alpine, areas above tree line,[4] elevations year round in the Cascade and Olympic Mountains.

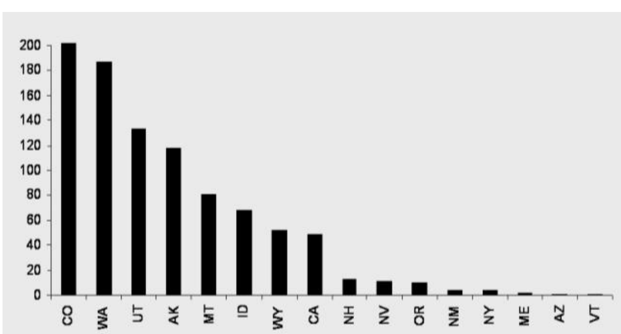

Figure 1-3 Avalanche Fatalities by State

As shown in Figure 1-3, Washington ranks second behind Colorado in fatalities from avalanches with 187 from 1950 to 2006.[5] In the United States since the year 2000, there have been an average 200 people reported caught in avalanches each winter: 90 were partly buried or buried, 32 were injured, and 28 were fatalities. United States property losses due to avalanches in this same period ranged from a low of $30,000 to a high of $2 million. The largest accident in Washington involving an avalanche, known as the Wellington Disaster, occurred in 1910 when two trains near Stevens Pass were swept off the tracks killing 96 passengers on board.

Although there is not any recorded history of a catastrophic disaster in this state from an avalanche, the potential for this hazard to cause massive destruction exists. A recent disaster from an avalanche took 50,000 lives in Iran in 1990 burying many villages in its path. The inhabitants of Yungay, Peru experienced a similar fate in 1970 when an earthquake triggered an avalanche on the slopes of Nevado de Huascarán sending millions of tons of snow into the valley below (Figure 1-4). The city and its 20,000 inhabitants were buried under 100 million cubic yards of snow, mud and rubble. Only 92 people survived.[6]

Figure 1-4 Aerial Photo of 1970 Yungay, Peru Avalanche

Assessment

The Washington State Department of Transportation (WSDOT) is the state agency tasked with avalanche control for major state highways. Specially trained avalanche control teams are stationed in winter months in the city of Hyak near the summit of Snoqualmie Pass on Interstate 90 and at Berne Camp near the summit of Stevens Pass on US Highway 2. The team's purpose is to decrease the hazard of avalanches and reduce the duration of winter highway closures for motorists. These teams initiate passive and active controls on paths affecting highways in order to keep people recreating, traveling, living, and working safe from the dangers of an avalanche. Active avalanche controls encompass the intentionally triggering of an avalanche, using artillery shells or charges on an unstable hillside. Such active control measures help manage the timing and size of avalanche occurrences, thus reducing traffic delays and minimizing injuries to motorists and winter sports enthusiasts (Figure 1-5). Passive controls such as snow sheds over the highway and elevated roadways are built so avalanches can pass over or under the road. (Figure 1-6). In addition to these controls the WSDOT closes three passes in winter because avalanches are so prevalent, that control measures would be too costly and hazardous.[7] These passes are Chinook Pass (elevation 5,430′) that connects Enumclaw

Figure 1-5 Use of Explosives to Prematurely Trigger Avalanche on Stevens Pass

Figure 1-6 Snow shed over Interstate 90 Westbound

and Yakima, Cayuse Pass (elevation 4,675′) that connects Chinook and White Pass along the east slope of the Cascades, and Rainy/Washington Passes (elevations 4,855′ and 5,500′) along the North Cascades Highway, which connects the Skagit Valley to eastern Washington. This portion of the North Cascades Highway holds the distinction of being among the top areas in the United States, for most avalanche chutes per mile of highway. Some areas of this highway have five avalanche paths in a mile of roadway.[8] Specific times of the winter when these passes close varies from year to year and is based on snow accumulation, personnel, avalanche risk, and a variety of other factors. Opening for the passes varies as well, although the target date for their opening is May 1 to coincide with the beginning of fishing season.

Avalanche control is a winter-long task on the two primary travel corridors in Washington that must remain open all year long. The more heavily impacted corridors are Interstate 90 -Snoqualmie Pass (elevation 3,022′); the primary East-West corridor serving the Seattle-Tacoma-Olympia area and US Highway 2 - Stevens Pass (elevation 4,061′) connecting Everett and Wenatchee. Snoqualmie Pass is the only interstate highway link in Washington through the Cascades. It averages 450 inches of snowfall each winter and has traffic volumes of over 32,000 vehicles a day, including 8,000 trucks. Interstate 90 is closed an average of eighty hours per year due to avalanches.[9] It is estimated that a two-hour closure of Snoqualmie pass costs the state's economy over $1 million.

With the advent of global warming coming into worldwide focus, it is necessary to take into account the potential effects this climate crisis may have on the dangers associated with avalanches. The research done so far indicates the potential for avalanches to become more frequent and deadly, as global warming effects the melting of permafrost, the permanent frozen layer of snow that gives our mountains and peaks their distinctive look. Already, the melting of permafrost can be blamed on several recent Alpine disasters, including the avalanches, which killed more than 50 people at the Austrian resort of Galtur in 1999.[10]

Backcountry recreation such as skiing, snowboarding, and snowshoeing have become increasingly popular over the years. As the popularity of these and other winter sports increases, the amount of people possibly exposed to these areas will continue to increase. From the resort ski areas, skiers and snowboarders can venture into avalanche zones. Signs for warning of this hazard are posted outside the groomed ski area but are often ignored. Personal locator beacons are a great asset for those people who go into the backcountry and into these avalanche prone zones, but due to their high cost, many people venture into these areas without them. In addition, as with any technological advance, practice with such devices is critical to their effective usage. Unfortunately, there is also increasing evidence, which suggests that backcountry travelers may take more risk when equipped with than without beacons.

Thousands of avalanches occur in the mountains of Washington every winter. Hundreds of these incidents can affect travel over the mountain pass highways, and all present the potential for accidents, delays, and fatalities to the citizens of the State. Current mitigation strategies (see the Avalanche Section of the Washington State Enhanced Hazard Mitigation Plan) in place lessen the potential for impact by this hazard. However, the possibility still exists for avalanches to affect the people, economy, environment, and property of Washington.

Internet Resources

Northwest Weather and Avalanche Center
http://www.nwac.us

Weather and Snowpack Information for Washington State
http://www.nwac.us/media.htm

Real-time Mountain Cameras for Washington State Passes and Ski Areas
http://www.nwac.us/mtnweather.htm

Washington State DOT Information on Washington State Mountain Passes
http://wsdot.wa.gov/traffic/passes/

Washington State Department of Transportation Snow and Ice Removal Information
http://www.wsdot.wa.gov/winter/default.htm#removal

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Columbia Generating Station

Frequency	
People	1,000-10,000
Economy	$120B+
Environment	10%
Property	$100M+

Risk Level

- Frequency –Although there have been minor incidents at the Columbia Generating Station, a release has not occurred in the history of this facility.
- People – A worst-case scenario could eventually result in thousands of deaths.
- Economy – the Washington economy could lose billions of dollars from loss of jobs, reduced tourism, seriously harming the agricultural business of the entire State, and could cause businesses to relocate to other areas in and out of state.
- Environment – It is possible that 10% of the burrowing owl (Figure 2-1) could be lost since a large number make the Hanford Reservation, where the Columbia Generating Stations is located, their home. In addition, a relatively large population of Piper's Daisy, a state sensitive plant, and a newly described plant species, the milk vetch lives, on Rattlesnake Mountain, located within the Hanford boundaries. An incident at the Columbia Generating Station could potentially eradicate at least 10% of one or more of these species.
- Property – The impact to property could reach into the millions of dollars.

Hazard Area Map

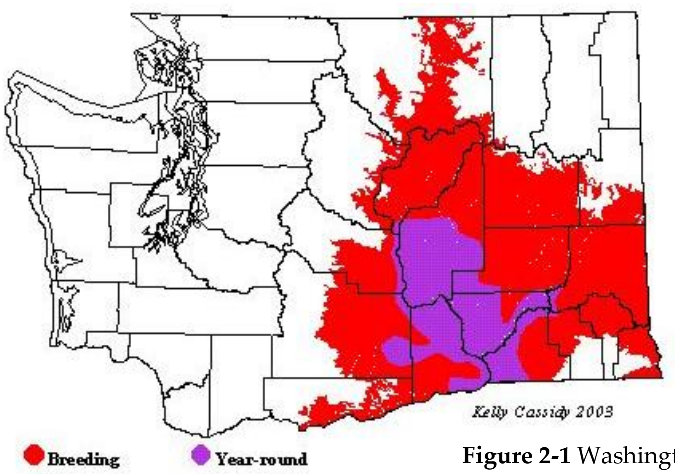

Figure 2-1 Washington Range Map: Burrowing Owls

The Columbia Generating Station (CGS) is located on the Hanford Reservation 6 miles north of Richland and 2 miles west of the Columbia River. In the map (Figure 2-2), the Immediate Response Zones 1 and 2 are located in Franklin County. Responses Zones 3A, 3B, 3C, and 4 are located in Benton County.

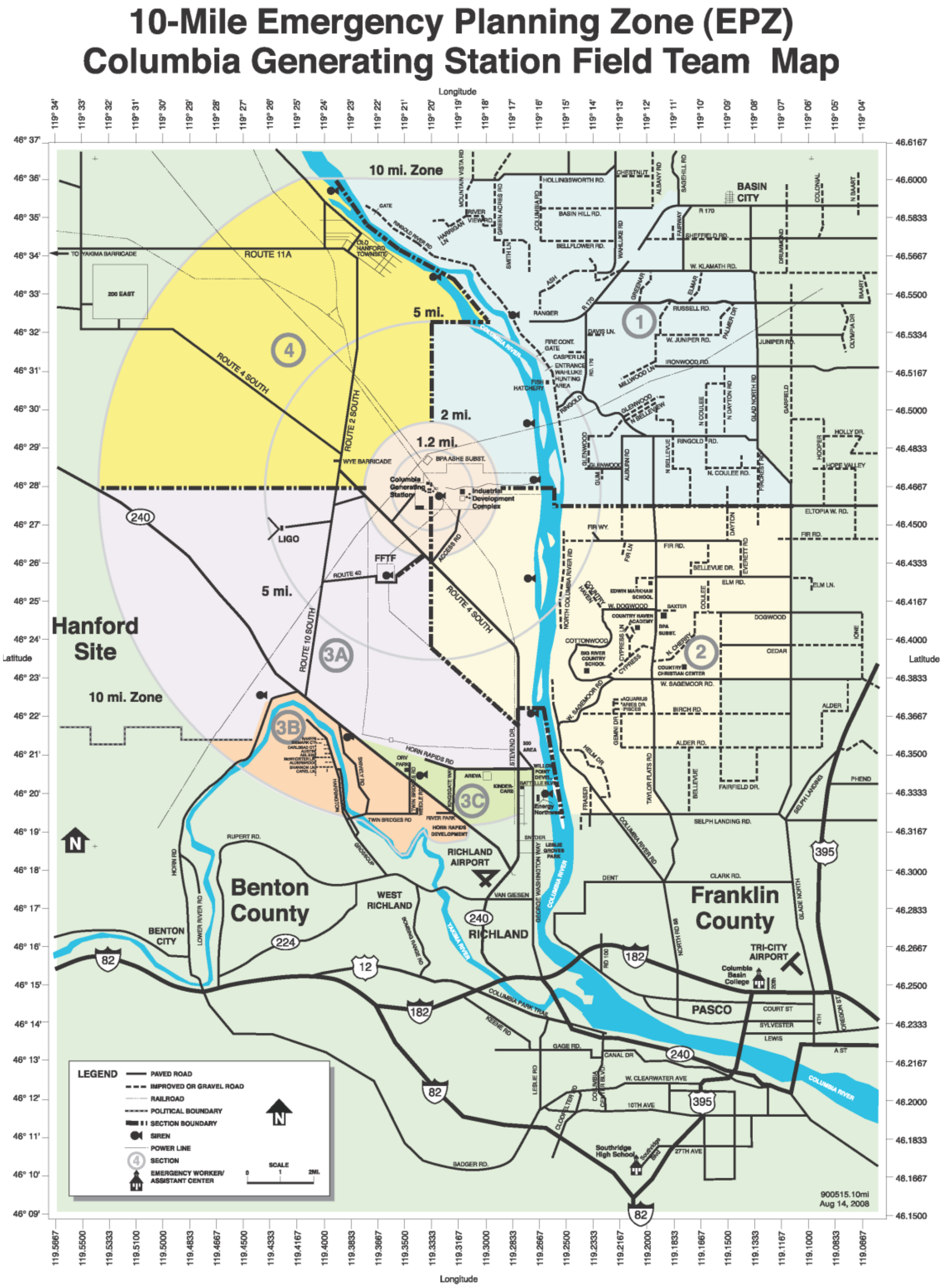

Figure 2-2 Columbia Generating Station 10-Mile Emergency Planning Zone Map

Definition

Energy Northwest's Columbia Generating Station (CGS) is Washington's only operating commercial nuclear power plant.

CGS (Figure 2-3) is a boiling water reactor and produces 1,150 megawatts of electricity – enough to meet the needs of a city the size of Seattle. This electricity is sold at cost to Bonneville Power Administration (BPA).

Figure 2-3 Columbia Generating Station Nuclear Power Plant

CGS is a reliable energy producer. Unlike hydro, wind, and solar generation facilities, CGS is not dependent on weather conditions — it will produce electricity 24 hours a day, 7 days a week, unless it is safely shut down by plant operators, as it is during a refueling outage. In addition, operators are able to adjust power levels to meet Bonneville Power Administration's needs based on river conditions; referred to as "load following." Refueling and maintenance outages occur every two years during the spring, when the Columbia River Basin has ample runoff to generate electricity through hydroelectric turbines.[11]

History

There are two partially completed reactors on this site; construction for both began in the late 1970s for the former Washington Public Power Supply System. WNP-4 was about 22% complete when it was terminated in 1983. Construction on WNP-1, at 63%, was stopped in 1982. Neither plant ever had a nuclear core installed.

This site covers 1,089 acres of Benton County, on the Hanford site of the Department of Energy. Five commercial reactors were initially planned for the State by the Washington Public Power System, but Units 4 and 5 were cancelled in 1982. Units 1 and 3 were cancelled in 1995. Construction of Unit 2 began in 1972, but more than a decade passed before it began generating power. Since the retirement of Oregon's Trojan Nuclear Plant, it is the only fully licensed commercial reactor in the northwestern United States. In 2000, Washington Public Power System changed its name to Energy Northwest and the plant's name to the Columbia Generating Station. The change is not merely in name. The reactor performed at 78% capacity in 2005, 99% capacity in 2006, 83% capacity in 2007, and 99% in 2008.

There have been several worldwide nuclear release accidents (see radiological incident section) but there have been no incidents of radiological release at the Columbia Generating Station. A list of some of the minor incidents that have occurred at CGS is below.

Date	**Incident Description**	**Notification Level**
14 May 1997	Explosion at the Plutonium Reclamation Facility (200 West Area)	Alert
28 January 1998	Picric Acid crystals found in 327 building (300 Area)	Alert
28 June 2000	24 COMMAND Range Fire (started in Benton County and came on-site. Threatened multiple facilities throughout the Hanford Site)	Alert
24 August 2005	Solid Waste Storage and Disposal Facility incident(200 West Area)	Alert
25 June 2004	Radiography vehicle stolen, vehicle later recovered	Alert
30 July 2004	Failure of two control rods to properly insert into the reactor	Alert
6 November 2005	Fast Flux Test Facility (FFTF) incident (400 Area)	Alert
28 March 2006	Range brush fire threatened the protected area near CGS	Alert

Figure 2-4 Minor incidents that have occurred at CGS in recent history

Assessment

The primary concern at the Columbia Generating Station is a potential release of radiological material. To ensure the likelihood is minimized, there are emergency plans in place and annual exercises conducted. In addition safety inspections are performed at the plant to ensure proper operation and safety procedures are followed.

Benton County Emergency Services, in coordination with Franklin County Emergency Management, the State of Washington, and Energy Northwest have developed plans to respond in the event of an accident at CGS. These plans are designed to help protect area residents, specifically those living within the Emergency Planning Zones (EPZ) around the nuclear power plant.[12] These plans are reviewed and updated routinely.

Two EPZs have been established as a basis for preparing to protect the public. Emergency plans for residents living up to ten miles from a nuclear facility, the plume EPZ, include ways to protect them from direct exposure to radiation in the event of a release of radioactive material.

Persons located up to fifty miles from a nuclear facility reside in the ingestion EPZ (Figure 2-5). Emergency plans for those in the ingestion EPZ include ways to protect them from consuming contaminated food. Examples of food or drink that can become contaminated with radiation are milk, fresh fruits, vegetables, processed products, and open water sources.[13]

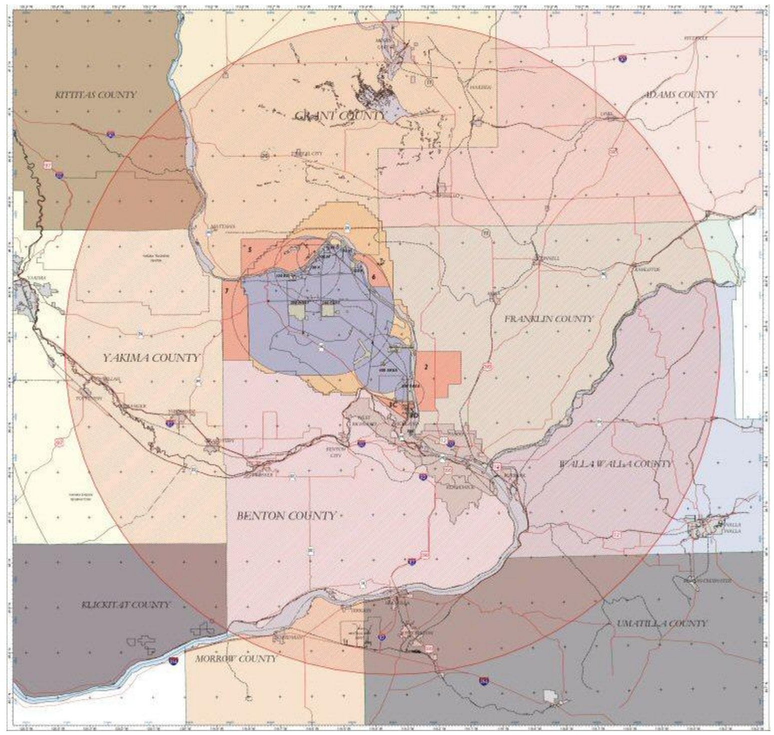

Figure 2-5 50-Mile Ingestion Emergency Planning Zone

The U.S. Nuclear Regulatory Commission (NRC), created as an independent agency by Congress in 1974 to enable the nation to use radioactive materials safely for beneficial civilian purposes while ensuring the protection of people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, through licensing, inspection and enforcement of its requirements. CGS is regulated by the NRC, which has issued a license to operate through 12/20/2023 (Figure 2-6).The NRC provides regular inspections of all nuclear facilities, with any deficiencies found being required to be immediately corrected. The results of nuclear facility inspections are publicly available documents and posted on the Internet.[14]

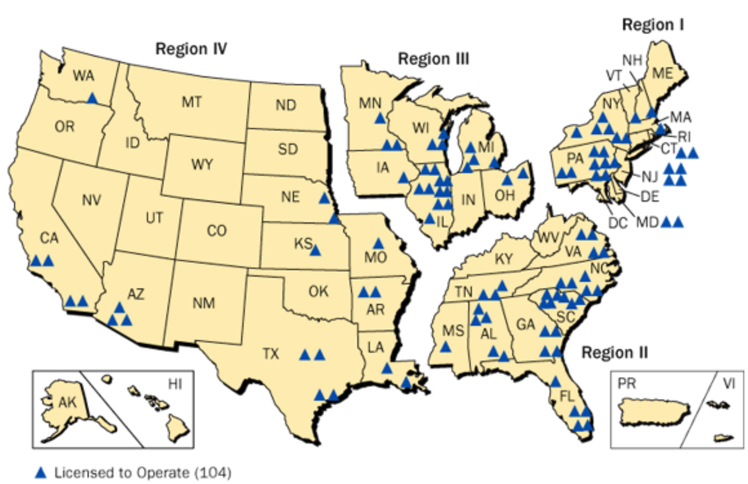

Figure 2-6 NRC-Licensed Nuclear Facilities by NRC Region

The NRC is the Coordinating Agency for radiological events occurring at NRC-licensed facilities. As Coordinating Agency, NRC has technical leadership for the Federal government's response to the event. If the severity of an event rises to the level of General Emergency, or is terrorist-related, the Department of Homeland Security (DHS) will take on the role of coordinating the overall Federal response to such an event. If this should occur the NRC would continue to retain a technical leadership role, in cooperation with other Federal agencies who may respond to an event at an NRC-licensed facility, or involving NRC-licensed material. Other federal agencies that may be involved in such an event include: the Federal Emergency Management Agency (FEMA), the Department of Energy (DOE), the Environment Protection Agency (EPA), the Department of Agriculture (USDA), the Department of Health and Human Services (DHHS), the National Oceanographic and Atmospheric Administration (NOAA), and the Department of State.[15]

Every level of government works cooperatively to ensure safety is the first priority for the operators of the Columbia Generating Station. While consequences from a release of radiological material from CGS could be dire, the efforts to protect the public from this potential hazard are unmatched.

Internet Resources

Energy Northwest, Columbia Generating Station
http://www.energy-northwest.com/generation/cgs/index.php

Energy Facility Site Evaluation Council, Nuclear Projects
http://www.efsec.wa.gov/nuclearproj.shtml

Washington Military Department Emergency Management Division,
Columbia Generating Station Nuclear Power Plant
http://emd.wa.gov/telcom/telcom_columbia_generating_station.shtml

Oregon Nuclear Safety Columbia Generating Station
http://www.oregon.gov/ENERGY/NUCSAF/cgs.shtml

Energy Information Administration, U.S. Nuclear Plants
http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/columbia.html

Bonneville Power Administration, Sounding Board
http://www.bpa.gov/power/pl/pnrisb/02-11-2004_Mtg_Handout3.pdf

Department of Energy- Hanford Site
http://www.hanford.gov/?page=338&parent=326

Franklin County Emergency Management
http://www.franklinem.org/

Benton County Emergency Services
http://www.bces.wa.gov/columbia_generating_station.htm

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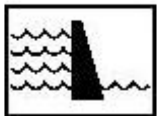
Dam Failure/Levee Break

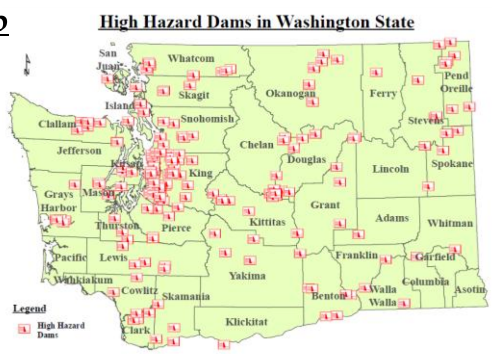


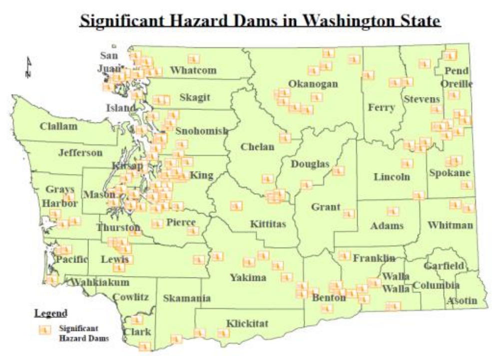
Frequency	1-10 yrs,
People	0-50,000
Economy	1% GDP
Environment	
Property	$100-500M

Risk Level

- Frequency – There is a dam failure in Washington once every two years.
- People – Depending on the location of the dam or levee, failure of either of these types of structures could affect zero to thousands of people depending on the population located downstream from the structure.
- Economy – The economy of Washington could be affected by a levee or dam failure due to loss of homes and businesses, thus lowering the overall tax base for the affected area.
- Environment – Although the environment can be severely affected by a dam failure or levee break due to the flood that results in this type of incident, the likelihood that such as incident will eradicate 10% of a single species or habitat is considered unlikely and thus does not meet this category's minimum threshold.
- Property – Property can be dramatically affected in the event of a dam failure or levee break. Should such a failure occur above a highly populated area, damages can be expected to be at least $100 to $500 million dollars or higher.

Hazard Area Map





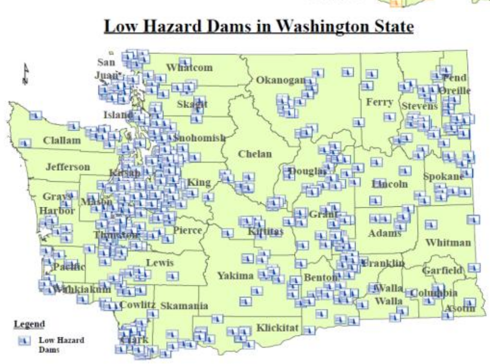


Figure 3-1 Low, Significant and High hazard Dams in Washington State. Classification of High, Significant and Low hazard for dams in Washington based on a combination of the size of the dam and the population that could be affected downstream should a failure occur. These classifications were established by the Washington State Department of Ecology – Dam Safety Office.

Definition

A dam is defined as an artificial barrier that can or does impound more than 10 acre-feet of water. Dam failure is the uncontrolled release of impounded water resulting in downstream flooding, which can affect life and property. Heavy periods of rain, flooding, earthquakes, blockages, landslides, lack of maintenance, improper operation, poor construction, vandalism, or terrorism can all result in dam failures. A levee is an embankment raised to prevent a river from overflowing. Levees are also small ridges or raised areas bordering an irrigated field.

History

Figure 3-2 Neighborhood resulting from the Seminary Hill Reservoir Failure

Washington has had 14 notable dam failures in the last century. Of these 14 events 3 are included in this section due to their resulting loss of life or high dollar damage estimates. The Eastwick Railroad Fill Dam near North Bend failed February 1932 resulting in the destruction of the railroad line and destroyed the village of Eastwick resulting in the death of 7 residents. The Seminary Hill Reservoir located near the city of Centralia failed in October of 1991 (Figure 3-2). Although this failure did not result in any loss of life, 3 million gallons of water drained from the reservoir in less than 2 minutes, resulted in the complete destruction of two homes, and damaged many others. Total damage estimates of this dam failure were around $3 million. Lastly, a waste pond dam operated by the Iowa Beef Processors company located in Wallula near Richland failed on January 1993. This failure resulted in the release of 300 acre-feet of waste water and washed away a Union Pacific railroad track resulting in the derailment of five locomotives. This dam failure resulted in the highest dollar amount for damages so far, at $5 million[16]

Another dam failure occurred in 1976 at the Teton Dam, ID that was a $100 million dollar earthen dam just built by the U.S. government. The failure of this dam occurred as it was being filled for the first time and resulted in the destruction of several thousand homes located in nearby towns and killed 11 people.

The most notable dam failure in the U.S. occurred in 1889 in the small western Pennsylvania town of Johnstown. The earthen dam built to create a lake for an exclusive hunting and fishing club collapsed after a period of heavy rainfall in May, releasing 20 million gallons of water toward the town of Johnstown (Figure 3-3). This dam collapse completely destroyed the town and resulted in the deaths of 2,200 Johnstown residents.[17]

Figure 3-3 Destruction caused by the Dam Failure of Johnstown, PA. May 1889

Assessment

The preponderance of responsibility for ensuring dam safety in Washington falls to the Washington Department of Ecology's Dam Safety Office. There are over 1,000 structures in the state that meet the definition of a dam (Figure 3-4). State and Federal agencies are responsible for ensuring that citizens are safe from failing dams, and that dams meet set safety standards.

Dams are constructed in Washington for a variety of purposes including: irrigation water supply, domestic water supply, recreation, wastewater treatment and storage, flood control, mine tailings storage, and hydroelectric power production. While irrigation and recreation serve as the majority of purposes of dams in our state, Figure 3-5 shows the diversity of dams in Washington.

Agency of Jurisdiction	Number of Washington State Dams
U.S. Army Corps of Engineers	19
U.S. Bureau of Reclamation	35
Other Federal	15
Federal Energy Regulatory Commission (non-Federal hydropower dams)	76
Washington Department of Ecology	870
Total of dams	1015

Figure 3-4 Jurisdictions for Dams in Washington

There are currently 870 dams in Washington that regulated by the Dam Safety Office. This number continues to increase as 10 to 15 dams are constructed each year. About 306 (35%) of the 870 dams under Ecology's jurisdiction are located above populated areas and are therefore classified as having high or significant downstream hazards. This number of high and significant hazard dams continues to increase as new dams are being built and more development continues to take place downstream from existing dams. But as Figure 3-6

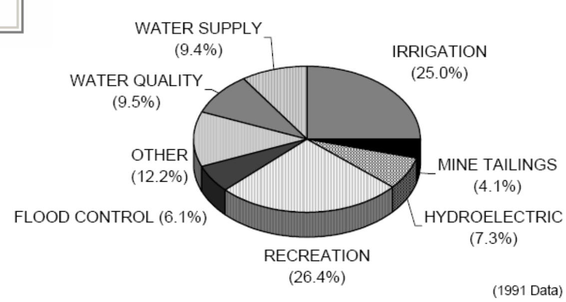


Figure 3-5 Dam Use Regulated by the Washington Department of Ecology

shows, most dams regulated by the Washington Department of Ecology – Dam Safety Office are in the small (<15 feet in height) to medium (15 to 49 feet in height) category for dams.

Height of Dam / Hazard	< 15 feet	15-49 feet	>50 feet
High (7 or more population at risk)	36	66	17
Significant (1 to 6 population at risk)	78	97	12
Low (0 population at risk)	402	157	4
Totals	516	320	33

Figure 3-6 Numbers of Dams by Height/Hazard, Regulated by the Dam Safety Office.

Despite best efforts to promote dam safety and assist owners in maintaining their dams in a safe manner, dam failures sometimes occur. Reasons for dam failures include:

- Overtopping – 34% of all failures nationally
  - Includes inadequate spillway design, debris blockage of spillway, and settlement of Dam Crest
- Foundation Defect – 30% of all failures nationally
  - Includes differential settlement, sliding and slope instability, high uplift pressures, and uncontrolled foundation seepage
- Piping and Seepage – 20% of all failures nationally
  - Includes internal erosion through dam caused by seepage "piping", seepage and erosion along hydraulic structures such as an outlet, conduits or slipways, or leakage through animal burrows, and cracks in the dam
- Conduits and Valves – 10% of all failures nationally
  - Includes piping of embankment material into conduit through joints or cracks
- Other various charges – 6% of all failures nationally

The authority and responsibility to regulate dams in Washington and to provide for the public safety are contained in the following: *RCW 90.03 – State Water Code*; *RCW 86.16 – Floodplain Management*; and *RCW 43.21A – Department of Ecology*. When water projects involve dams and reservoirs with a storage volume of 10 acre-feet or more of water, these laws make provisions, which require engineering reviews of the construction plans and specifications, for the inspection of the dams, and require remedial action to reasonably secure proper operation, maintenance, and continued safe performance of the dam.

Periodic inspections of existing dams are conducted in areas where dam failure and release of the reservoir contents could pose the potential for loss of life. The inspections are done to ensure that deficiencies are found and corrected, to determine that the dam is being operated safely, and to confirm that maintenance of the dam is being performed. The frequency with which these inspections are performed is included in the *Water Resources Program Policy 5404*. When deficiencies are found at an inspected dam, the dam owner is responsible for correcting those deficiencies. If the owner fails to correct deficiencies at the dam, the dam can be declared a public nuisance and removed through an abatement proceeding in Washington Superior Court.

The majority of failures result from inadequate maintenance and monitoring of facilities. Failure of a dam can have many effects such as loss of life and damage to structures, roads, utilities, crops, and the environment. Economic losses from a dam failure could include a lowered tax base, because of homes and businesses lost in a dam failure event.

The failure to implement a suitable operation and maintenance program at dams is a common thread in dam incidents occurring in Washington. Many municipalities operate old reservoir systems and find it difficult to fund effective operation and maintenance programs. While the failure of projects with a high hazard potential for loss of life are increasingly remote, the number of failures of low hazard projects that provide important infrastructure roles are on the rise. With the state population increasing every year, homes are frequently being constructed downstream from dams. Dams rated at the low hazard rating are not built to the more stringent requirements of high hazard dams, and these represent the greatest potential threat to public safety. The Department of Ecology's Dam Safety Office (DSO) is attempting to examine these smaller dams and get them on a schedule for comprehensive inspections and repair.

Periodic inspections are conducted on existing dams that are located in areas where dam failure and release of reservoir contents could pose the potential for loss of life. The inspections are intended to identify deficiencies, and to reasonably assure that safe operation and confirm that maintenance is being adequately performed. Inspections are performed by the Department of Ecology every 5 years for dams with high downstream hazard classifications, and every 10 years for dams with significant hazard classifications. The inspections are performed by professional engineers from the Dam Safety Office and involve: review and analysis of available data on design, construction, operation, and maintenance of the dam and its appurtenances; visual inspection of the dam and its appurtenances; evaluation of the safety of the dam and its appurtenances, which may include assessment of the hydrologic and hydraulic capabilities, structural stabilities, seismic stabilities, and other conditions which could constitute a hazard to the integrity of the structure; evaluation of the downstream hazard classification; evaluation of the operation, maintenance, and inspection procedures employed by the owner and/or operator; and review of the emergency action plan for the dam including review and/or update of dam breach inundation maps. The Department of Ecology prepares a comprehensive report of the findings of the dam inspections, which includes findings from the inspections, and any required remedial work to be performed.[18]

Washington also has levees interspersed around the state that function as flood control structures. In 2007, Congress passed the National Levee Safety Act, which for the first time directed the Army Corps of Engineers to inventory all private levees in the nation[19]. The funding for this project is not expected to be allotted until the 2009 Congressional session. Without this knowledge, it is hard to assess the hazard and risk to Washington citizens, property, and environment do to levees. When this inventory is available and the condition of all the levees in Washington is known, a hazard and risk assessment may be recommended.

While periodic inspections are the basis for limiting the risk of dam failure, increasing the level of disaster preparedness, including evacuation routes, notification procedures, and personal preparedness training and hazard awareness in communities downstream from high hazard dams may also play a factor in lessening the outcome of a dam failure, should one occur.

Internet Resources

Washington State Department of Ecology, Dam Safety Office
www.ecy.wa.gov/programs/wr/dams/dss.html

Federal Emergency Management Agency, Dam Failure Disaster Information
www.fema.gov/hazard/damfailure/df_before.shtm

Washington State Department of Ecology, Dam Safety Emergency Response
www.ecy.wa.gov/programs/wr/dams/Emergency.html

Drought

Frequency	1-10 yrs.
People	
Economy	2-3% GDP
Environment	
Property	$200-300M

Risk Level

- Frequency – Based on the 100-year history of drought in Washington, the state as a whole can expect severe or extreme drought conditions at least every five years, with most of eastern Washington experiencing severe or extreme drought more frequently.[20]
- People – While people are definitely affected by a drought, lives are usually not lost due to this hazard.
- Economy – The two worst droughts in the state's history (1977 and 2001) resulted in thousands of job losses to the power and agricultural industries as well as job losses in the mining, recreation, and fishing industries. In addition, the estimated losses to the state's economy due to these two drought events were close to $500 million.
- Environment – While the presence of drought can increase the likelihood of wildfires and result in significant damage to the environment, this damage is not expected to completely alter 10% of a habitat or eradicate 10% of a single species, and therefore does not meet the minimum threshold for this category.
- Property – During Washington's last drought in 2005, the Washington State Department of Agriculture made a preliminary estimate of the potential impact of this drought on Washington's agriculture industry. Assuming a worst-case scenario of below average precipitation throughout the growing season, WSDA anticipated that crop losses would be between $195 and $299 million, or 5 to 8% of the Washington harvest.[21]

Hazard Area Map

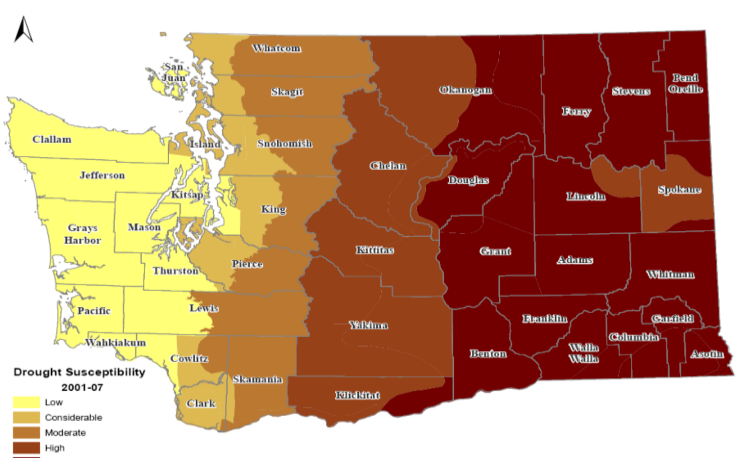


Figure 4-1 Drought Susceptibility for Washington State 2001-2007

The drought susceptibility map of Washington (Figure 4-1) was generated by analyzing U.S. Drought Monitor data from the years 2001 through 2007. The National Drought Mitigation Center (NDMC) releases a Drought Severity Index Map of the country once a week, indicating the drought severity level, if any, across the U.S. For this map, GIS data layers were obtained for the first week in each month from January 2001 to December 2007.

For each Drought Monitor index file, the drought severity-level polygons for Washington were clipped out of the original layer and used for this map. Each of the new, drought severity files for Washington were then overlaid onto the National Weather Services' weather forecast zones for the state. The forecast zones were then given a number rating for the month and year of the drought severity forecast based on level of severity of drought. The drought intensity ranged from 1 for abnormally dry conditions to 5 for exceptional drought conditions. When forecast zones had no drought level indicated, the zone was given a zero rating for that specific month and year.

For zones in which two levels of drought severity were present, the zone was given the rating that included the largest overall area between the two drought severity indicators. Drought severity levels for each month and year between 2001 and 2007 were then totaled and divided by the number of months analyzed to give an indication of the likelihood of drought in these zones. As we can see from the map, the eastern portion of Washington has a higher susceptibility to drought then the western portion of the state. This observation coincides with the weather pattern differences experienced in western Washington which experiences more average rainfall per year then in eastern Washington.

Definition

A drought is defined as "a period of drier-than-normal conditions that results in water-related problems."[22] Unlike other hazards that have a sudden onset of the incident, a drought happens over a period of time from weeks, months, to even several years. Washington is different from most states in that it "has a statutory definition of drought consisting of two parts:

- An area has to be experiencing, or projected to experience, a water supply that is below 75% of normal, and

Figure 4-2 Lake Roosevelt (mouth of the Colville River) in Stevens County, April 25, 2005. During normal flow, much of this land would be under water.

- Water users within those areas will likely incur undue hardships as a result of the shortage."

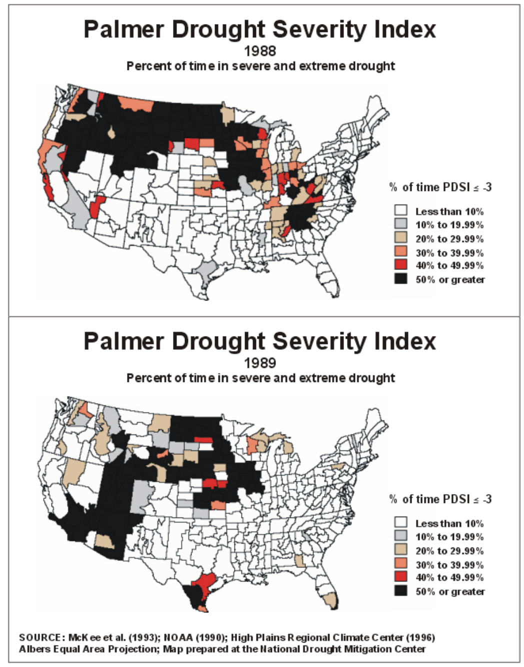


Figure 4-4 Drought Severity map for 1988-89 Drought. This map shows the area's most affected by the 1988-89 Drought as the percent of time of severe and extreme drought conditions.

History

In Washington, "droughts are a natural part of the climate cycle. In the last century there have been a number of drought episodes, including several that have lasted for more than a single season,

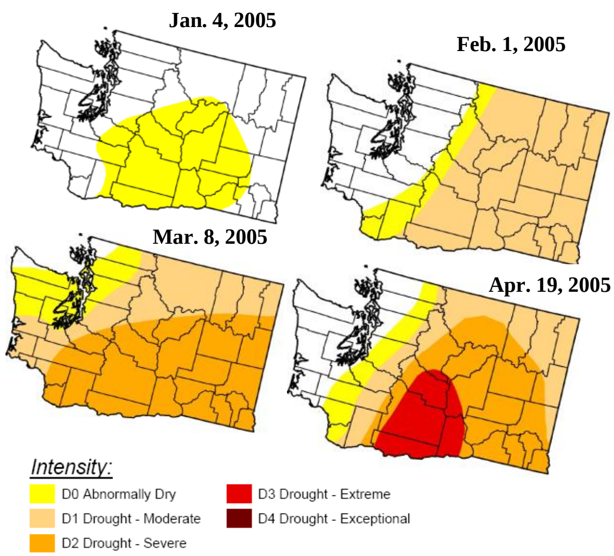


Figure 4-3 U.S. Drought Monitor Maps from the 2005 Drought

such as dry periods between 1928-32 and 1992-94". The worst drought in Pacific Northwest history was in 1977. This drought resulted in low precipitation for Seattle, Tacoma, and Olympia and closed ski resorts in the Cascades for much of the 1976-77 ski season.[23] The 1977 drought set many "current records for low precipitation, snowpack, and stream flow totals. More recently, the 2001 drought turned out to be the second-worst in state-recorded history".[24] The 2001 drought in Washington also occurred in much of the western and southeastern portions of the United States. "Between November 2000 and March 2001, most of the (Washington's) rainfall and snowpack totals were only about 60 percent of normal." "As late as mid-January (2001), most of the state was largely unaffected; by mid-March, moderate to severe drought conditions gripped the entire state." Drought conditions continued to worsen throughout the spring and summer months, with conditions not falling back to normal until mid-February 2002.[25] The most recent drought in Washington occurred in 2005 (Figure 4-2). Like the drought in 2001, the 2005 drought also came on quite rapidly (Figure 4-3). "From December 2004 through February 2005, precipitation dropped to near record lows across Washington, between 51 and 76 percent of average. Eastern Washington received less than 10 percent of normal precipitation in February, and Western Washington did not very much more precipitation then this. By

March, mountain snowpack was only 26% of normal." As late as mid-January 2005, most of Washington seemed to be unaffected by drought conditions. "By March, moderate to severe drought conditions gripped the entire state". By April 2005 much of Eastern Washington, including those areas used for much of Washington's agriculture industry were in a moderate to extreme drought.

The drought between 1988 and 1989 (Figure 4-4) that occurred in a large portion of the U.S. resulted in "severe losses to agriculture and related industries, with an estimated loss of $15 billion just in agriculture output. According to the National Climatic Data Center (NCDC) the overall cost of the event was $39-40 billion".[26] "Although the 1988-1989 Drought was the most economically devastating natural disaster in the history of the United States, a close second is undoubtedly the series of droughts that affected large portions of the United States in the 1930's".[27] While "the 1930's drought is often referred to as if it were one episode, there were at least 4 distinct drought events: 1930-31, 1934, 1936, and 1939-40 (Figure 4-5). These events occurred in such rapid succession that affected regions were not able to recover adequately before another drought began".

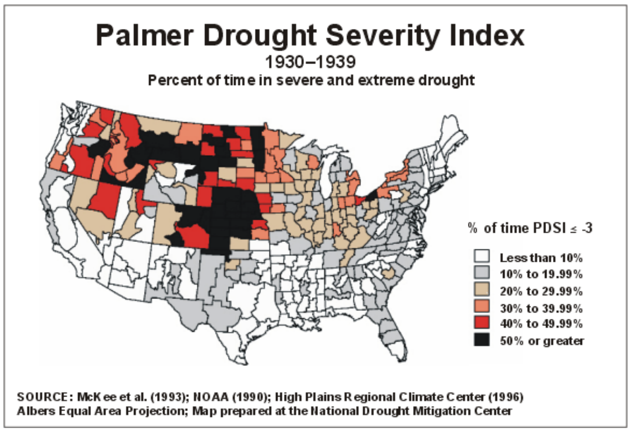


Figure 4-5 Drought Severity Map. This map shows the area's most affected by the 1930's era drought as the percent of time of severe and extreme drought conditions

Often referred to as the "Dust Bowl Years", these droughts hit the Midwestern United States the hardest in the form of agricultural losses. Many crops in this region were lost or damaged due to "deficient rainfall, high temperatures, and high winds, as well as insect infestations and dust storms that accompanied these conditions". Although it is not entirely possible to count all the costs associated with these series of drought, financial assistance from the federal government has been estimated to have "been as high $1 billion (in 1930s dollars) by the end of the drought". The drought and "its associated impacts finally began to abate during spring 1938. By 1941, most areas of the country were receiving near-normal rainfalls".

Assessment

The "Pacific Northwest's (PNW) climate and ecology are largely shaped by the interactions that occur between seasonally varying atmospheric circulation (i.e. weather) patterns and the region's mountain ranges. Approximately two-thirds of the region's precipitation occurs in just half the year (October-March) when the PNW is on the receiving end of the Pacific storm track (Figure 4-6) much of this precipitation is captured in the region's mountains, influencing both natural and human systems…"[28] Unlike other parts of the country, "snow- rather than man –made reservoirs- is the dominant form of water storage, storing water from the winter (when most precipitation falls) and releasing it in spring and early summer, when economic, environmental, and recreational demands for water" are greatest throughout the state.[29] The amount of snow that collects in Washington's mountains largely depends on both precipitation and the temperature during winter months. The El Niño and La Niña, southern oscillation events that occur in the Pacific Ocean, affect Washington's winter weather and play a role in whether the region experiences a drought. In El Niño years, winters tend to be drier and springtime temperatures tend to be warmer, the result is lower springtime snowpack and resulting stream flow during spring and summer in snowmelt driven rivers. These factors make "drought more likely, during warm phase" El Niño years.

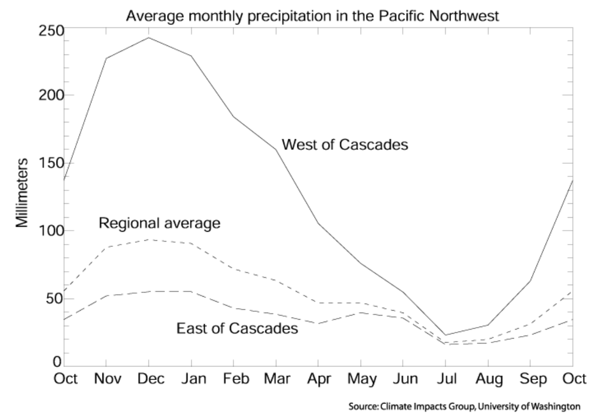


Figure 4-6 Average Monthly Precipitation in the Pacific Northwest for 1900-1998

With global climate change becoming an increasing concern, it is beneficial to understand its potential impact on drought. "With projected global temperature increase, some scientists think that the global hydrological cycle will also intensify".[30] Large-scale models of the Earth's atmosphere "indicate that global precipitation could increase 7-15%. Meanwhile, global evapotranspiration could increase 5-10%. Thus, the combined impacts of increased temperature, precipitation, and evapotranspiration will affect snow, runoff, and soil moisture conditions". These models "generally show that precipitation will increase at high latitudes and decrease at low and mid-latitudes. Therefore, in mid-continent regions, evapotranspiration will be greater than precipitation and with a potential for more severe, longer-lasting droughts in these areas".

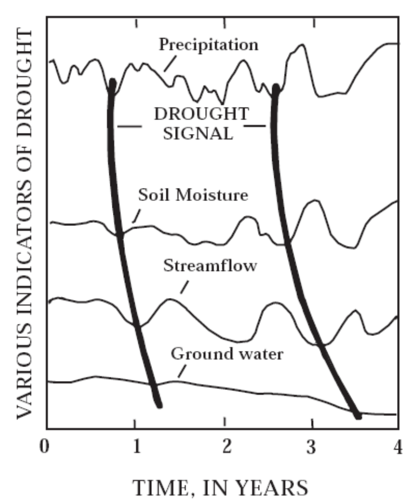


Figure 4-7 Drought Signal. As the drought signal goes from left to right, the drought signal becomes more pronounced but time also increases.

"The beginning of a drought is difficult to determine. Several weeks, months, or even years may pass before people know that a drought is occurring". "The first evidence of a drought is seen in records of rainfall (Figure 4-7). Within a short period, the amount of moisture in soils can begin to decrease. The effects of a drought on flow in streams and rivers or on water levels in lakes and reservoirs may not be noticed for several weeks or months". "Scientists don't know how to predict drought a month or more in advance for most locations. Predicting drought depends on the ability to forecast two fundamental meteorological surface parameters, precipitation and temperature".[31]

"The impacts of drought are greater than the impacts of any other natural hazard. They are estimated to be $6-8 billion annually in the United State and occur primarily in agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts".[32] "Society's vulnerability to drought is affected by (among other things) population growth and shifts, urbanization, demographic characteristics, technology, water use trends, government policy, social behavior, and environmental awareness. These factors are continually changing, and society's vulnerability to drought may rise or fall in response to these changes."

"Although drought is a natural hazard, society can reduce its vulnerability and therefore lessen the risks associated with drought episodes. The impacts of drought, like those of other natural hazards, can be reduced through mitigation and preparedness (risk management)."

Internet Resources

National Drought Mitigation Center, University of Nebraska-Lincoln
www.drought.unl.edu

National Oceanic and Atmospheric Administration, Drought Information Center
www.drought.gov

Climate Impacts Group, University of Washington – Joint Institute for the Study of the Atmosphere and Ocean and The Center for Science in the Earth systems, Climate Change Scenarios
http://cses.washington.edu/cig/fpt/ccscenarios.shtml

Earthquake

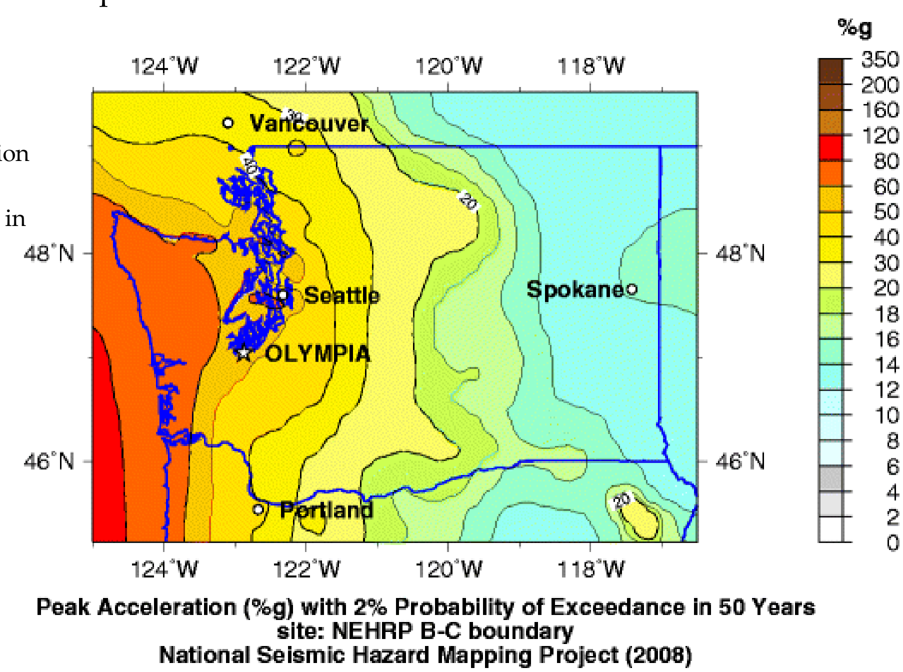
Frequency	Annually
People	0-10,000+
Economy	1% GDP
Environment	
Property	$1B+

Risk Level

- Frequency – Minor earthquakes occur daily in Washington. Larger magnitude earthquake, which result in damage, occur less frequently in the state.
- People – The population affected in an earthquake depends on many variables that need to be known to make a proper assessment. Generally, these variables include the magnitude of the earthquake, the population present in the areas of strongest shaking, the time of day, the age of buildings affected, etc. With these variables in mind it is considered plausible that an earthquake in the state could affect anywhere between 0 and 10,000 or more people.
- Economy – The economy affected by an earthquake depends on variables similar to the population affected. It is plausible to estimate that a large magnitude earthquake near the major Puget Sound ports in Olympia, Seattle, Tacoma, or Everett could cause significant damage to the state's economy.
- Environment – The type of environmental impact or damage that occurs in the event of an earthquake does not meet the minimum threshold for this category.
- Property – Property damage could be in excess of $1 billion dollars in the event of a catastrophic earthquake.

Hazard Area Map

Figure 5-1 Peak Acceleration (gravity % (g)) with 2% Probability of Exceedance in 50 Years



The hazards map (Figure 5-1), produced by the U.S. Geological Survey (USGS), display the percent Peak Ground Acceleration (PGA) (gravity %) of an earthquake with 10% probability of exceeding in 50 years. The map shows how the State's PGA is much higher in the heavily populated and highly urbanized Puget Sound region than in other parts of the state.

Definition[33]

An earthquake is a sudden release of stored energy. Most earthquakes occur along a fault. A fault (Figure 5-2) is a fracture along which the blocks of the Earth's crust on either side have moved relative to one another parallel to the fracture. Strike-slip faults are vertical (or nearly vertical) fractures where the blocks have mostly moved horizontally. Dip-slip faults are inclined fractures where the blocks have mostly shifted vertically. Oblique-slip faults have significant components of both slip styles.

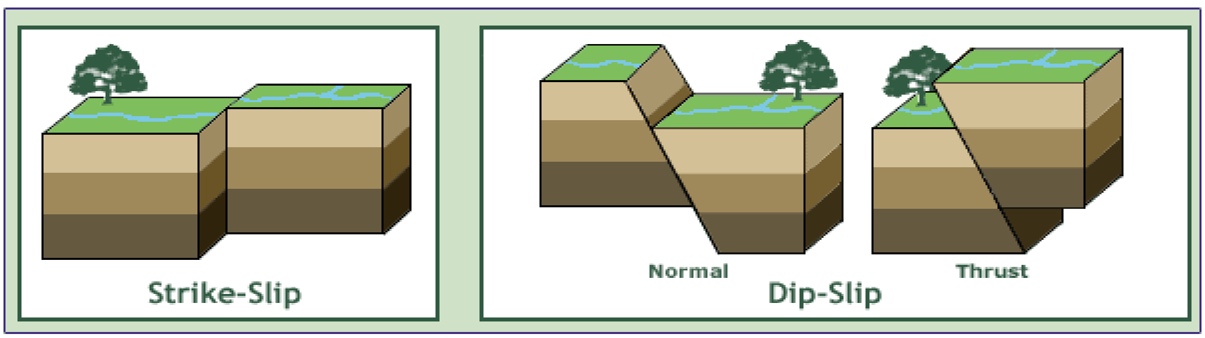


Figure 5-2 A graphic representation of strike-slip and dip-slip earthquakes.

Earthquake magnitude is a logarithmic measure of earthquake size. In simple terms, this means that at the same distance from the earthquake, the shaking will be 10 times as large during magnitude 5.0 earthquakes as it is during magnitude 4.0 earthquakes. The total amount of energy released by the earthquake, however, goes up by a factor of 32.

Intensity scales such as the Mercalli (Figure 5-3) are based on the observations of the strength of shaking. Intensity varies with distance from the source and with effects near the observer, such as ground-motion amplification by soft soils.

The Modified Mercalli Scale		Level Of Damage	The Richter Scale
1-4	Instrumental to Moderate	No damage.	/= 4.3
5	Rather Strong	Damage negligible. Small, unstable objects displaced or upset; some dishes and glassware broken.	4.4 - 4.8
6	Strong	Damage slight. Windows, dishes, glassware broken. Furniture moved or overturned. Weak plaster and masonry cracked.	4.9 - 5.4
7	Very Strong	Damage slight-moderate in well-built structures; considerable in poorly-built structures. Furniture and weak chimneys broken. Masonry damaged. Loose bricks, tiles, plaster, and stones will fall.	5.5 - 6.1
8	Destructive	Structure damage considerable, particularly to poorly built structures. Chimneys, monuments, towers, elevated tanks may fail. Frame houses moved. Trees damaged. Cracks in wet ground and steep slopes.	6.2 - 6.5
9	Ruinous	Structural damage severe; some will collapse. General damage to foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground; liquefaction.	6.6 - 6.9
10	Disastrous	Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land.	7.0 - 7.3
11	Very Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.	7.4 - 8.1
12	Catastrophic	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted.	8.1

Figure 5-3 Comparison of Mercalli and Richter earthquake magnitude scales

History[33]

Washington, and more specifically the Puget Sound region, has a history of frequent earthquakes. More than 1,000 earthquakes occur in the state each year. A dozen or more of these earthquakes are of high enough magnitude that people can feel ground shaking. The most destructive outcome of an earthquake is the damage and loss of life that can result due to such an event. Large earthquakes in 1946 (magnitude 5.8), 1949 (magnitude 7.1), and 1965 (magnitude 6.5) killed 15 people and caused more than $200 million (1984 dollars) in damage throughout several counties in Washington.

Location	Date	Magnitude
Prince William Sound	1964	9.2
Cascadia Subduction Zone, Pacific Northwest	1700	~9
Rat Islands, Alaska	1965	8.7
Andreanof Islands, Alaska	1957	8.6
East of Shumagin Islands, Alaska	1938	8.2
Unimak Islands, Alaska	1946	8.1
New Madrid, Missouri	1811	8.1
Yakutat Bay, Alaska	1899	8.0
New Madrid, Missouri	1812	~8
Denali Fault, Alaska	2002	7.9

Figure 5-4. The ten largest earthquakes in U.S. recorded history

The state has experienced at least 20 damaging earthquakes in the past 125 years. Of these past earthquakes, the following events are described in more detail:

Olympia Earthquake – April 13, 1949
This was a magnitude 7.1 earthquake centered about eight miles north-northeast of Olympia. Property damage in the Seattle, Tacoma, and Olympia area was estimated at $25 million (1949 dollars). Eight people were killed with many more injured because of this earthquake.

School buildings were seriously damaged in the impact area, including 30 schools that served 10,000 students. Ten schools were condemned and permanently closed because of the damage they sustained from this earthquake. Chimneys on more than 10,000 homes required repairs. In Centralia, an estimated 40% of all homes and businesses were damaged.

Seattle-Tacoma Earthquake – April 29, 1965
This earthquake struck the Puget Sound region at a magnitude 6.5, a depth of 40 miles, and centered about 10 miles north of Tacoma. This earthquake caused an estimated $12.5 million (1965 dollars) worth of damage and killed seven people.

Most damage in Seattle was concentrated in areas of filled ground, including Pioneer Square and the Seattle Waterfront, of which both contain older masonry built buildings. Nearly every waterfront building experienced damage during this event. Extensive chimney damage occurred in West Seattle. Low-lying and filled areas along the Duwamish River and its mouth settled causing severe damage at Harbor Island and slumping along Admiral Way in Seattle. Buildings with unreinforced brick-bearing walls with sand-lime mortar were damaged most severely in this event. However, wood frame dwellings, such as residential homes, feared excellent in this quake with most damaged confined in cracks in plaster or to failure of unreinforced brick chimneys near the roofline.

The Bonneville Power Administration substation near Everett sustained damage to two electric transmission substations. In addition, three water mains in Seattle, and two of the three water supply lines in Everett broke or sustained heavy damages.

Nisqually Earthquake – February 28, 2001
This earthquake was at a magnitude 6.8 and centered under Anderson Island about 11 miles northeast of Olympia. The depth of this earthquake was calculated at 36.7 miles. The area of most intense ground shaking occurred along the densely populated Interstate 5 corridor region and not directly around the epicenter of the earthquake. This was due to the amplification of energy waves from the earthquake on the softer river valley sediments common to this area. The six counties most severely damaged by the earthquake – King, Kitsap, Lewis, Mason, Pierce, and Thurston – were declared federal disaster areas (Federal Disaster #1361) one day after the event. Eventually, 24 counties received disaster declarations for Stafford Act assistance.

Various estimates have placed damage to public, business, and household property at $1 billion to $4 billion due to the Nisqually Earthquake. To date Stafford Act assistance provided is estimated at $155.9 million. Approved Small Business Loans are estimated at $84.3 million and Federal Highway Administration emergency relief is estimated at $93.8 million as a result of this earthquake. A study by the University of Washington funded by the Economic Development Administration of the U.S. Department of Commerce, estimated that 20% of small businesses in the region affected by this earthquake had a direct physical loss and 60% experienced productivity disruptions.

Assessment[33]

The earthquake threat in Washington is not uniform (See Figure 5-1). While most earthquakes occur in western Washington, some damaging events, such as the 1872 magnitude 6.8 (estimated), occur east of the Cascades. Geologic evidence documents prehistoric magnitude 8 to 9.5 earthquakes along the outer coast, and events of magnitude 7 or greater along the shallow crustal faults located within the urban areas of Puget Sound.

Washington's earthquake hazards reflect its tectonic setting. The Pacific Northwest is at a convergent continental margin, the collision boundary between two tectonic plates of the Earth's crust. The Cascadia Subduction Zone, the fault boundary between the North American plate and the Juan de Fuca plate, lies off the coast of Washington from northern

California to southern British Columbia, Canada. These two plates are converging at a rate of approximately 2 inches per year. In this subduction zone, the northern Pacific plate is pushing the Juan de Fuca plate north, causing complex seismic strain. A sudden release of the seismic strain along this fault causes earthquake.

Because of the subduction process, the state is vulnerable to earthquakes originating from three sources: the subducting plate (an Interplate or Benioff Zone earthquake), between colliding plates (a Subduction Zone earthquake), and in the overriding plate (a Shallow Crustal earthquake).

Subducting Plate Earthquake (Interplate or Benioff Zone)
Subducting plate earthquakes occur within the subducting Juan de Fuca plate at depths of 15 to 60 miles, although the largest events occur at depths of 25 to 40 miles. The largest recorded event of this type was the magnitude 7.1 Olympia earthquake in 1949.

The probability of future occurrence for earthquakes of this kind, like the 1965 magnitude 6.5 earthquake in the Seattle-Tacoma area and the 2001 magnitude 6.8 Nisqually Earthquake, is about once every 35 years. The approximate reoccurrence rate for earthquakes of this type similar to the magnitude 7.1 earthquake in Olympia in 1949 is approximately once every 110 years.

Colliding Plates Earthquake (Subduction Zone)
Subduction zone earthquakes occur along the interface between tectonic plates. Scientists have found evidence of great-magnitude earthquakes along the Cascadia Subduction Zone. These earthquakes are very powerful, with a magnitude of 8 or 9 or greater. This type of earthquake occurs at intervals between every 100 to 1,100 years. The last of these great earthquakes struck Washington in 1700. Scientists currently estimate that a magnitude 9 earthquake in the Cascadia Subduction Zone occurs about once every 350 to 500 years.

Overriding Plate Earthquakes (Shallow Crustal)
This type of earthquake occurs within about 20 miles of the surface. Recent occurrences of this type of earthquake occurred in Bremerton in 1997, near Duvall in 1996, and off of Maury Island in 1995. These earthquakes had a magnitude between 5 and 5.5.

Scientists currently estimate the recurrence rate of a magnitude 6.5 or greater earthquake on the Seattle Fault at about once every 1,000 years. Recent research indicates the Darrington-Devils Mountain fault appears capable of generating an earthquake of magnitude 7.5. The Southern Whidbey Island fault appears to be capable of generating earthquakes of magnitude 7.0 or greater.

Geologists continue to study these faults located in the Puget Sound region as they are of particular concern because 60% of the state's population and a large percentage of the state's economic base is located in this region. These scientists have yet to be able to determine the recurrence intervals for all known surface faults. However, they believe that a shallow earthquake of magnitude 6.5 or greater on one of the faults located in the Puget Sound region occurs about once every 333 years.

Four magnitude 7.0 or greater earthquakes shallow crustal earthquakes have occurred in Washington in the past 1,100 years, including two such earthquakes since 1918 on Vancouver Island, British Columbia. The scientific findings of surface faults is ongoing and may lead to a greater assessment of earthquake risk from these faults in Washington then currently perceived.

In terms of economic impact, Washington ranks second in the nation after California among states susceptible to economic loss caused by earthquakes, according to a Federal Emergency Management Agency (FEMA) study. This study predicts that the state faces a probable annualized loss of $228 million due to earthquake; average annualized loss is an equivalent measure of future losses averaged on an annual basis. Seattle ranks 7th and Tacoma ranks 22nd on a list of cities with more than $10 million in annualized earthquake losses.

To determine the counties most vulnerable to earthquakes in Washington, the State Hazard Mitigation Plan used two primary factors:

1. The Annualized Earthquake Loss, as calculated by the FEMA earthquake modeling software HAZUS-MH
2. The Annualized Earthquake Loss Ratio, as calculated by HAZUS-MH

Counties considered most at risk were those counties with an Annualized Earthquake Loss of at least $1 million or with an Annualized Earthquake Loss Ratio equal or greater than the State's ratio of 0.05. Twenty-two of the state's thirty-nine counties met one of the criteria for vulnerability.

In addition, the counties of Chelan, Kittitas, and Walla Walla, which have a greater seismic risk than most counties in eastern Washington, but lack the building stock to meet the above vulnerability criteria, were added to the list of counties vulnerable to earthquakes. This decision was based on advice from seismologists and federal and state geologists with expertise on the seismic hazards in Washington.

Other factors the State Hazard Mitigation Plan (HMP) included in the assessment of a jurisdictions vulnerability was the size of the potentially vulnerable population and the age of the residential building stock. These factors included:

- The jurisdiction's population who speak English as a second language
- The jurisdiction's population with disabilities, or are considered senior citizens
- The jurisdiction's population living in poverty
- The population of school aged (K-12) children living in the jurisdiction
- And, the percentage of the residential building stock in each jurisdiction that was built before 1960

Based on these factors, the following counties are considered at the greatest risk and most vulnerable to earthquake:

- Mason
- Benton
- Island
- Spokane
- Chelan
- Jefferson
- Clallam
- Walla Walla
- Pierce
- Kitsap
- Cowlitz
- Whatcom
- Snohomish
- Pacific
- Clark
- Skagit
- Wahkiakum
- San Juan
- Kittitas
- Grays Harbor
- Yakima
- Thurston
- King
- Lewis

The earthquakes faults in Washington are complex, and research continues to be conducted on them. Although seismic monitors exist throughout our region that alarm us to when an earthquake is occurring, it is not yet possible to predict when the next earthquake in Washington will strike. Knowing the vulnerability and risk to earthquakes in Washington can help to steer mitigation measures and personal preparedness education toward lessening the social and economic impact from such an event in the future.

Internet Resources

Federal Emergency Management Agency
http://www.fema.gov/hazard/earthquake/index.shtm

United States Geological Survey
http://earthquake.usgs.gov/

Washington State Department of Natural Resources
http://www.dnr.wa.gov/ResearchScience/Topics/GeologicHazardsMapping/Pages/earthquakes.aspx

Washington State Emergency Management Division
http://emd.wa.gov/hazards/haz_earthquakes.shtml

Pacific Northwest Seismic Network
http://www.ess.washington.edu/SEIS/PNSN/

National Oceanic and Atmospheric Administration:
http://www.ngdc.noaa.gov/hazard/earthqk.shtml

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Epidemic/Pandemic

Frequency	30-50 yrs
People	50,000+
Economy	1-2% GDP
Environment	
Property	

Risk Level

- Frequency – According to most health experts, a pandemic happens two or three times a century.
- People – According to the pandemic modeling software, FluAid, developed by the U.S. Center for Disease Control, over 1 million people in Washington can expect to become ill if a severe pandemic, such as the 1918 pandemic event, were to occur today.
- Economy – During an epidemic/pandemic, businesses that provide goods and services temporarily close, adversely affecting the economy of our state. The 1918 flue pandemic caused schools and businesses to close temporarily. The flu arrived in Washington in September of 1918 with some schools not reopening until January or March of 1919.[34]
- Environment – A pandemic or epidemic events is not expected to adversely affect 10% of a species or habitat and thus does not meet the minimum threshold for this category.
- Property – A pandemic/epidemic event will not adversely affect the property of the state of Washington and thus does not meet the minimum threshold for this category.

Hazard Area Map

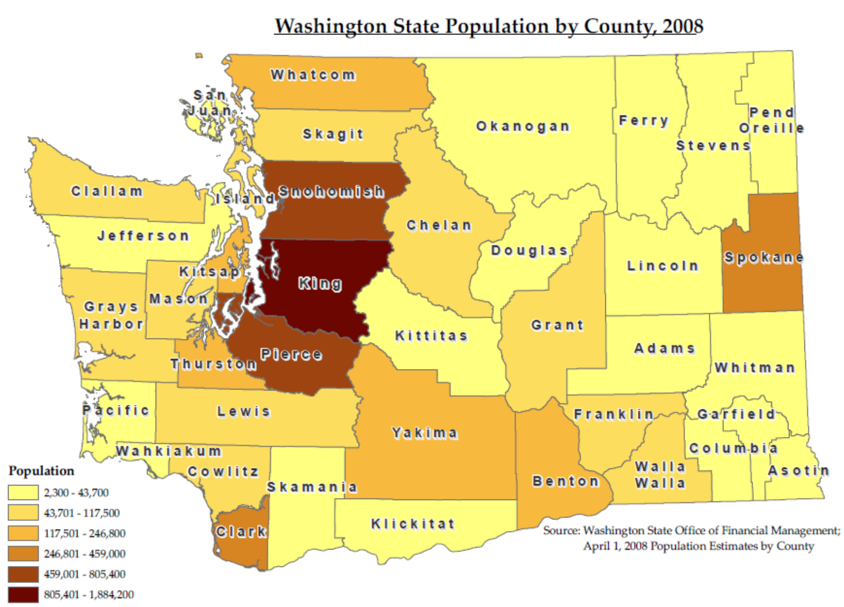

Figure 6-1 Estimates of Washington State Population by County as of April 2008

The population of the area in which the virus is introduced will largely influence the quantity of people affected by an epidemic or pandemic. From the population by county map (Figure 6-1); the greatest populations in Washington exist in King, Pierce, and Snohomish counties. These counties should consider their large populations when planning and preparing for the next epidemic or pandemic.

When looking at the death tolls for previous flu pandemics, the number of deaths experienced was influenced by the population of the areas that it was introduced. In 1918, the largest concentrations of people in Washington lived in urban areas such as Seattle (1918 population 315,312), Tacoma (1918 population 96,965) and Spokane (1918 population 104, 437) with an overall state population of 1.35 million.[35] Death tolls for the 1918 influenza pandemic were much higher in these three cities then in other cities in the state (Figure 6-2), likely due to the large population of people living there.

Influenza Deaths by City (not including pneumonia)

Seattle	732
Spokane	282
Tacoma	205
N Yakima	104
Bellingham	71
Everett	64
Walla Walla	60
Aberdeen	21

1918 Flu Deaths By City

Influenza Mortality by City: (influenza + pneumonia)

Seattle	1,241
Spokane	50

Figure 6-2 1918 Pandemic Influenza Deaths in Washington State by City

Definitions

The following definitions concerning pandemics and epidemics were taken from the World Health Organization:

Pandemic – The worldwide outbreak of a disease in humans in numbers clearly in excess of normal; a global disease outbreak.

Panzootic – The worldwide outbreak of a disease in animals in numbers clearly in excess of normal.

Epidemic – A disease occurring suddenly in humans in a community, region or country in numbers in excess of normal.

Epizootic – A disease occurring suddenly in animals in a community, region or country in numbers clearly in excess of normal.

Zoonosis – Diseases that are transferable from animals to humans.

Infectious Agent – Any organism, such as a pathogenic virus, parasite, or bacterium, that is capable of invading body tissues, multiplying, and causing disease.

Virus – Any of various simple submicroscopic parasites of plants, animals, and bacteria that often cause disease and that consist essentially of a core of RNA or DNA surrounded by a protein coat. Unable to replicate without a host cell, viruses are typically not considered living organisms.

Avian Flu – A highly contagious viral disease with up to 100% mortality in domestic fowl caused by influenza A virus subtypes H5 and H7. All types of birds are susceptible to the virus but outbreaks occur most often in chickens and turkeys. The infection may be carried by migratory wild birds, which can carry the virus but show no signs of disease. Humans are only rarely affected

History

Pandemics of influenza have occurred throughout recorded history and have been documented since the 16th century. Since the well-documented pandemic of influenza-like disease occurred in 1520 there have been 31 influenza pandemics documented. Intervals between previous pandemics have varied from 11 to 42 years with no recognizable pattern. Three pandemics occurred in the last century. The most recent was in 1968/69, with prior to pandemics occurring in 1957/58 and 1918/19 (Figure 6-3).[36]

Pandemics Death Toll Since 1900	
1918-1919	
U.S....	675,000+
Worldwide...	50,000,000+
This as per the CDC	
1957-1958	
U.S....	70,000+
Worldwide...	1-2,000,000
1968-1969	
U.S....	34,000+
Worldwide...	700,000+

Figure 6-3 Pandemic Influenza Death Toll since 1900

The 1918/19 Influenza Pandemic "is the catastrophe against which all modern pandemics are measured. Before the 1918/19 pandemic, one has to go back to the "black death" (bubonic plague) of 1346 to find a similarly devastating epidemic in terms of total number of deaths". It is estimated that approximately 20 to 40 percent of the worldwide population became ill during the 1918/19 influenza pandemic. The number of worldwide deaths due to the pandemic was initially reported as 20 million, but consensus among experts now believe the death toll was at least 40 million with some believing it could have been as high as 50 to 100 million deaths. Between September 1918 and April 1919, approximately 500,000 to 650,000 deaths from the pandemic flu occurred in the U.S. alone. Western Samoa and Iceland were the only countries to avoid the 1918 flu entirely due to the use of strict travel restrictions during the pandemic.

The 1957/58 Influenza Pandemic was on the whole much milder than that of the 1918 influenza, with the global death toll reaching 2 million. The most recent influenza pandemic occurred in 1968 with the Hong Kong Flu outbreak, which resulted in nearly 34,000 deaths in the United States. The 1968/69 pandemic, which was much milder than 1957/58, it was thought to have caused around 1 million deaths worldwide. Due to advances in science from the 1918/19 influenza, worldwide vaccine production began in both the 1957/58 and the 1968/69 shortly after the pandemic began, likely lessening the death rates for both of these events.

Assessment

Several characteristics of pandemic or epidemic differentiate these episodes from other public health emergencies. First, an epidemic or pandemic has the potential to infect large numbers of Washington citizens, which could easily overwhelm the health care system in the state. A pandemic outbreak could also jeopardize essential community services by causing high levels of absenteeism in critical positions in every workforce. It is likely that vaccines against a new virus will not be available for six to eight months following the arrival of the virus in the United States. Basic public services such as health care, law enforcement, fire and emergency response, communications, transportation, and utilities could all be disrupted or severally lessened. Finally, the pandemic, unlike other public health emergencies, could last for several weeks or months. Pandemic influenza will affect many regions simultaneously and therefore outside resources may be unavailable.

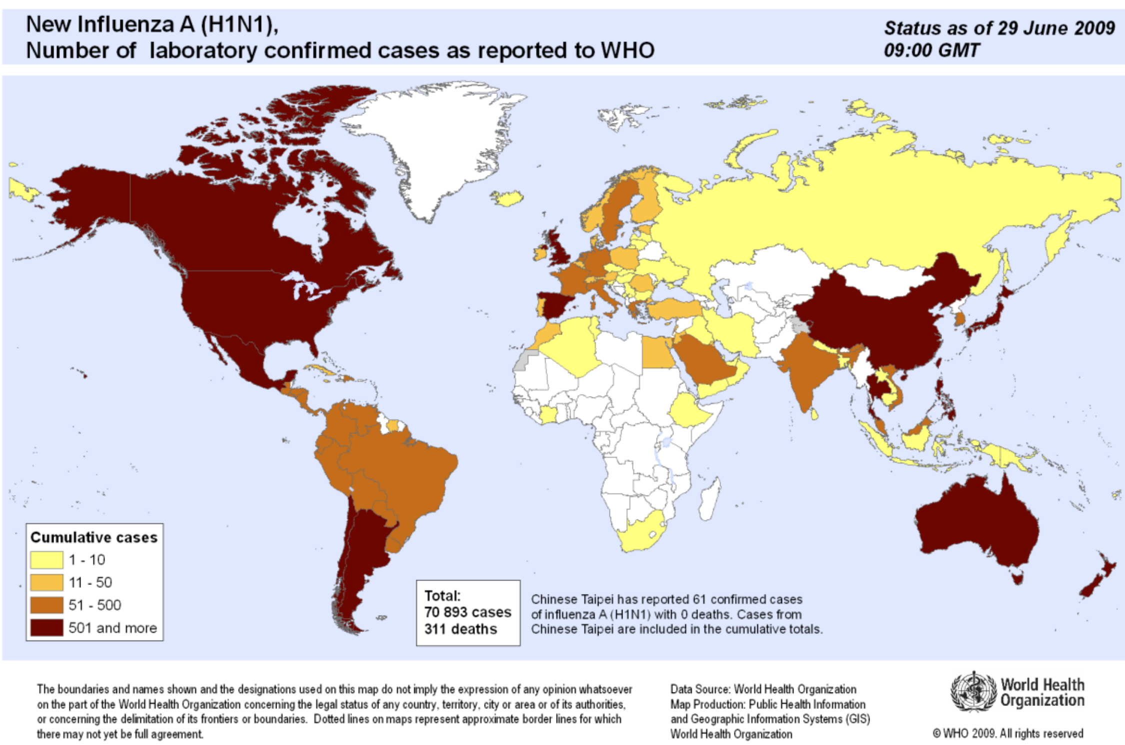

Figure 6-4 Nations with Confirmed Cases of the A/H1N1 Swine Flu Virus

"Novel influenza A (H1N1) is a new flu virus of swine origin that first caused illness in Mexico and the United States in March and April, 2009 (Figure 6-4). It is thought that novel influenza A (H1N1) flu spreads in the same way that regular seasonal influenza viruses spread, mainly through the coughs and sneezes of people who are sick with the virus, but it may also be spread by touching infected objects and then touching your nose or mouth. Novel H1N1 infection has been reported to cause a wide range of flu-like symptoms, including fever, cough, sore throat, body aches, headache, chills and fatigue. In addition, many people also have reported nausea, vomiting and/or diarrhea.

The first novel H1N1 patient in the United States was confirmed by laboratory testing at CDC on April 15, 2009. The second patient was confirmed on April 17, 2009. It was quickly determined that the virus was spreading from person-to-person. On April 22, CDC activated its Emergency Operations Center to better coordinate the public health response. On April 26, 2009, the United States Government declared a public health emergency and has been actively and aggressively implementing the nation's pandemic response plan.

Since the outbreak was first detected, an increasing number of U.S. states have reported cases of novel H1N1 influenza with associated hospitalizations and deaths. By June 3, 2009, all 50 states in the United States and the District of Columbia and Puerto Rico were reporting cases of novel H1N1 infection. While nationwide U.S. influenza surveillance systems indicate that overall influenza activity is decreasing in the country at this time, novel H1N1 outbreaks are ongoing in parts of the U.S., in some cases with intense activity.

CDC is continuing to watch the situation carefully, to support the public health response and to gather information about this virus and its characteristics. The Southern Hemisphere is just beginning its influenza season and the experience there may provide valuable clues about what may occur in the Northern Hemisphere in the fall and winter" of 2009.[37]

"On June 11, 2009, the World Health Organization (WHO) raised the worldwide pandemic alert level to Phase 6 in response to the ongoing global spread of the novel influenza A (H1N1) virus. A Phase 6 designation indicates that a global pandemic is underway. More than 70 countries are now reporting cases of human infection with novel H1N1 flu. This number has been increasing over the past few weeks, but many of the cases reportedly had links to travel or were localized outbreaks without community spread. The WHO designation of a pandemic alert Phase 6 reflects the fact that there are now ongoing community level outbreaks in multiple parts of world. WHO's decision to raise the pandemic alert level to Phase 6 is a reflection of the spread of the virus, not the severity of illness caused by the virus. It is uncertain at this time how serious or severe the novel H1N1 pandemic will be in terms of how many people infected will develop serious complications or die from novel H1N1 infection. Experience with this virus so far is limited and influenza is unpredictable. However, because novel H1N1 is a new virus, many people may have little or no immunity against it, and illness may be more severe and widespread as a result. In addition, currently there is no vaccine to protect against novel H1N1 virus.

In the United States, most people who have become ill with the newly declared pandemic virus have recovered without requiring medical treatment, however, CDC anticipates that there will be more cases, more hospitalizations and more deaths associated with this pandemic in the coming days and weeks. Also, this virus could cause significant illness with associated hospitalizations and deaths in the fall and winter during the U.S. influenza season"[37]. As of June 26, 2009, the Washington State Department of Health states that 86 hospitalizations and 3 deaths have been confirmed to be the result of the swine flu.

"Climate change is a significant and emerging threat to public health, and changes the way we must look at protecting vulnerable populations" (Figure 6-5). "The impacts of climate change on human health will not be evenly distributed around the world. Developing country populations, particularly in small island states, arid and high mountain zones, and in densely populated coastal areas, are considered to be particularly vulnerable". Fortunately, most of the health risk associated with climate change can be avoided through existing health programs and interventions. Concerted action to strengthen key features of health systems and to promote healthy development choices can enhance public health now as well as reduce vulnerability to the effects of future climate change.[38] The risk of a pandemic or epidemic event is not seen as being directly tied to changes in climate in the United States but may play a factor in the spread of such an outbreak in developing countries.

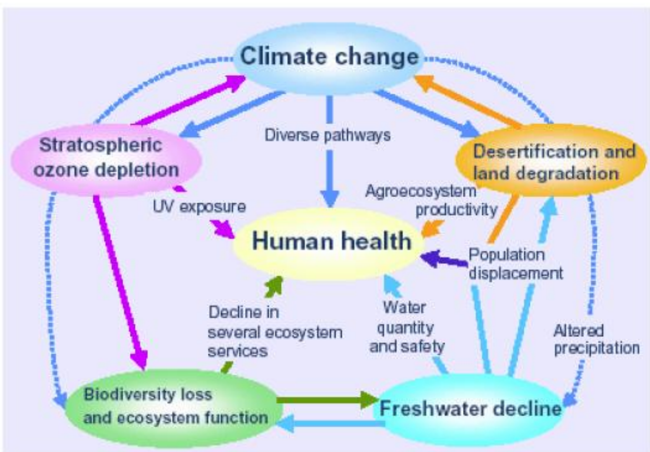

Figure 6-5 Human Health and the Effects of Climate Change

A pandemic influenza outbreak could kill hundreds of thousands of Americans and possibly more than 40,000 Washington citizens.[39] Unlike the ordinary flu, people of any age and health condition can become seriously ill and no one will have immunity to a pandemic flu virus. With a pandemic influenza, no one is immune to this virus and the normally considered vulnerable populations that include the elderly and young children may not be the only portions of the population most vulnerable to a pandemic influenza. In fact, the 1918 pandemic had a gross disproportion of 20 to 40 year olds die in the pandemic, a portion of the population not thought to be the most vulnerable to diseases (Figure 6-6). This was later found to be contributed to a large portion of this section of the population being carriers of tuberculosis, which weakened their immune system, but no

Influenza and Pneumonia Deaths in 1918 By Age

Age (yrs)	# Deaths
< 1	333
1	132
2	66
3	54
4	44
5-9	129
10-19	491
20-29	1243
30-39	1218
40-49	435
50-59	257
60-69	190
70-79	165
80-89	87
90-99	12

Figure 6-6 1918 Influenza Pandemic Deaths in Washington by Age

one knows what contributing factors may have an effect on susceptibility to the next pandemic.

Previously, there were no early warning systems in place for the past three pandemics. To reduce the risks of the next pandemic each country needs to have a communications strategy to educate the public about pandemic flu. Human-to-human transmission needs detected at the earliest to lessen and combat the effects of the next pandemic.[38]

In Washington, the Department of Health is working closely with federal agencies, various state agencies, local health officials and other to prepare for such an event.

Internet Resources

U.S. Department of Health and Human Services, Pandemic Flu Website
www.pandemicflu.gov

World Health Organization
www.who.int/en

DHHS- Center for Disease Control & Prevention, Diseases & Conditions
www.cdc.gov/DiseasesConditions/

Washington State Department of Health (WDOH),
Public Health Emergency Preparedness & Response
www.doh.wa.gov/phepr/default.htm

Federal Response Stages to Pandemic Flu
www.pandemicflu.gov/plan/federal/fedresponsestages.html

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Urban Fire

Frequency	Annually
People	
Economy	
Environment	
Property	$227M+

Risk Level

- Frequency – Fires in urban areas of Washington occur annually.
- People – An urban fire affecting 1,000 people or more is highly unlikely.
- Economy – The economy of Washington is not likely to be impacted by a fire in an urban area to the point that it meets the minimum threshold for this category.
- Environment – While an urban fire can affect habitat and species, the probability that the fire will destroy 10% of a habitat or kill 10% of a species is considered highly unlikely.
- Property – According to the "2008 Fire in Washington", report prepared by the Office of the State Fire Marshal, total property and content loss due to fire was estimated to be approximately $227 million dollars.

Hazard Area Map

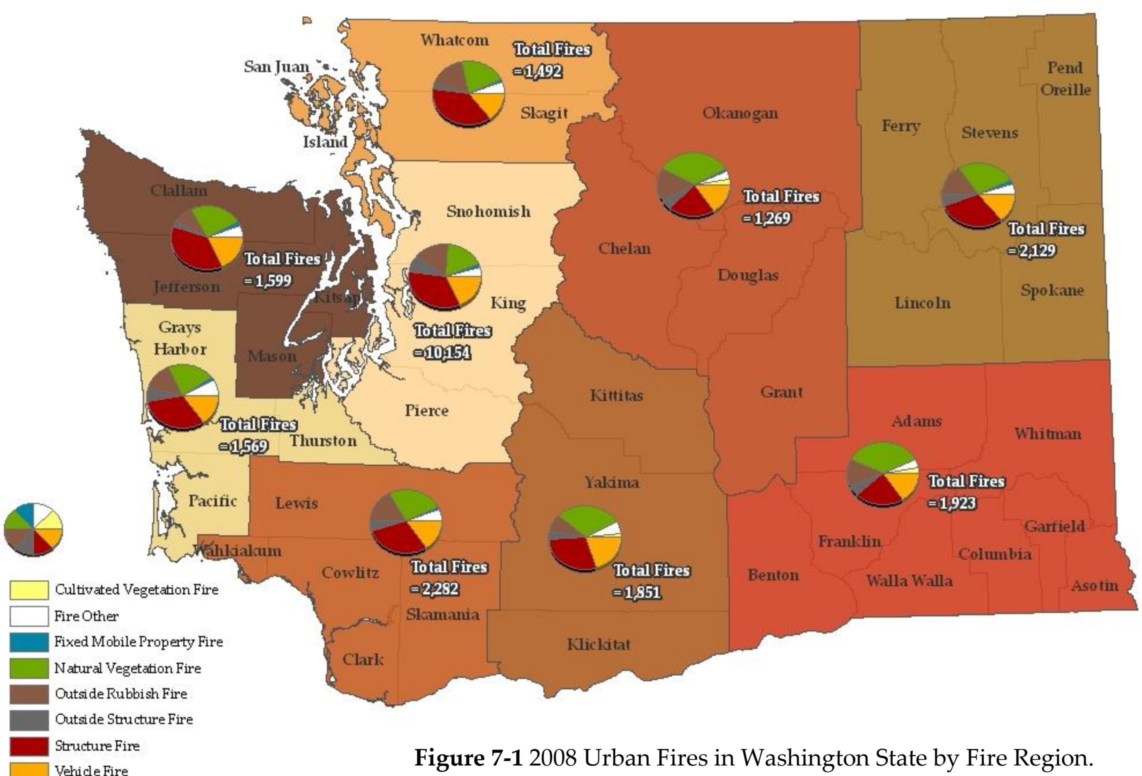

Figure 7-1 2008 Urban Fires in Washington State by Fire Region.
Data Source: "2008 Fire in Washington"

Definition

Urban fires are classified as “uncontrolled burning in a residence or building from natural, human or technical causes”.[40]

History

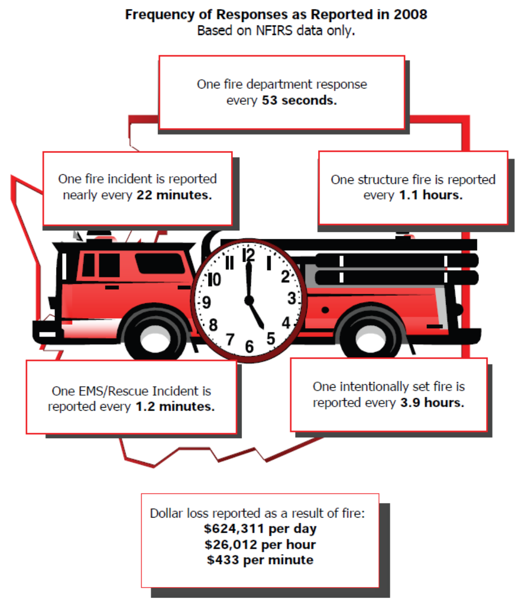

Figure 7-2 Frequency of WA Fire Department Responses in 2008 (Based on NFIRS data only)

Local city and county fire departments are tasked with the response and control of urban fires. These agencies respond to “nearly 1.8 million fire calls each year”[41] in the United States. In 2008, fire departments in Washington responded to nearly 600,000 calls (Figure 7-2) with over 24,000 of these due to urban fire.[42] These fire incidents caused an estimated $228 million dollars in damaged property and possession loss. While this number is staggering, it is estimated that the indirect costs of urban fires can be 8 to 10 times the estimated costs of the fire in the form of “temporary lodging, psychological damage, lost business, medical expenses, and others”. Last year one structure fire was reported every 1.1 hours with a resulting dollar loss of about $26,000 or over $624,000 a day (Figure 7-2). Structure fires in Washington resulted in 32% of the total fire incidents reported but resulted in 85% (Figure 7-3) of the total loss dollar estimate for the year. Washington’s residential property ranked second in number of fire incidents, but number one in dollar loss.[42]

Summary of 2008 Incident Type Categories

Incident Type Category	Total Number of Incidents	% of Total Incidents	Total Property and Content Loss Reported	% of Total Loss Reported
Fire	24,268	4.1%	$227,873,540	97.3%
Cultivated Vegetation Fires	*166*	*0.0%*	*$1,296,935*	*0.6%*
Fire, Other	*1,184*	*0.2%*	*$584,623*	*0.2%*
Fixed Mobile Property Fires	*296*	*0.0%*	*$2,658,863*	*1.1%*
Natural Vegetation Fires	*5,910*	*1.0%*	*$2,501,096*	*1.1%*
Outside Rubbish Fires	*3,587*	*0.6%*	*$620,676*	*0.3%*
Outside Storage & Equipment Fires	*1,387*	*0.2%*	*$776,463*	*0.3%*
Structure Fires (including confined fires)	*7,795*	*1.3%*	*$198,251,905*	*84.6%*
Vehicle Fires (Mobile Properties)	*3,943*	*0.7%*	*$21,182,979*	*9.0%*
Rescue and Emergency Medical Service	424,365	70.8%	$2,252,711	1.0%
Service Calls	39,178	6.5%	$1,424,287	0.6%
False Alarms & False Calls	41,908	7.0%	$927,025	0.4%
Malicious or Mischievous False Alarm	*9,418*	*1.6%*	*$3,650*	*0.0%*
Fire Protection System Malfunction	*11,264*	*1.9%*	*$412,700*	*0.2%*
Unintentional False Fire Protection System Activation	*21,226*	*3.5%*	*$510,675*	*0.2%*
Hazardous Conditions (No Fire)	12,309	2.1%	$665,611	0.3%
Severe Weather & Natural Disaster	442	0.1%	$555,400	0.2%
Good Intent Calls	49,541	8.3%	$357,591	0.2%
Overpressure Rupture, Explosion, Overheat (No Fire)	1,470	0.2%	$113,585	0.0%
Other Types of Incidents	5,530	0.9%	$43,300	0.0%
Undetermined Incident Type	46	0.0%	$0	0.0%
Grand Total	**599,057**	**100.0%**	**$234,213,050**	**100.0%**

Sorted by dollar loss.

Figure 7-3 Washington State Fire Department Responses for 2008

While the dollar amount lost to fire is considerably high, the loss of life due to fire in Washington remains lower than the national average. In 2008, there were 45 fire fatalities in Washington State representing a 12% decrease in fire related deaths from the previous year’s report.[42] This places Washington’s fire fatality rate at 6.8 people per million population.[42] "According to the last available national statistics (2005 figures) the fire fatality rate for the United States is 12.3 per million population – Washington ranked 15th lowest in the nation".[42]

Washington has had two notable large urban fires in its history, both occuring in 1889. The Great Seattle Fire occurred on June 6, 1889 and destroyed the entire central business district of Seattle. This fire burned the majority of 29 city blocks, including the central business district, four of the city's piers, and the railroad terminal. Only one person is known to have died in this fire and total losses were estimated around $20 million. The Spokane Fire occurred on August 4, 1889 and destroyed most of what what then downtown Spokane. With the advent of more modern fire fighting technology we are unlikely to experience such a fire of this magnitude again but recent urban fires of note have killed people and destroyed millions of dollars in property. A fire in the Ozark Hotel in Seattle on March 21, 1970 killed 19 people and the Great Ellensburg Fire of 1889 (July 4, 1889) destroyed 200 Victorian homes and 10 blocks of businesses.

Assessment

Structure fires represented 32% of the total urban fires reported in 2008. Among these fires, 28% were caused by operating equipment such as space heaters and stoves, or other conductive or radiated heat sources and 6% were caused by cigarette smoking. "Historically, smoking-related fires have been the leading cause of fire fatalities in Washington State, accounting for 17.7% of the deaths over the past five years. In 2008, smoking-related fire deaths fell to the fourth leading cause. Fatal fires most frequently occur in places where people live or sleep. In 2008, approximately 73% of the fire fatalities occurred in residential occupancies. Single-family dwellings alone accounted for 60% of the reported fire fatalities, including 8 deaths in mobile homes. Multi-family dwellings accounted for 13.3% of the [fire related] deaths"[42] in Washington in 2008 (Figure 7-4).

Places Fire Fatalities Occurred in 2008		
Categories	**Total**	**% of Total**
Single-Family Dwellings	27	60.0%
Multi-Family Dwellings	6	13.3%
Motor Vehicle	5	11.1%
Outside (including tents)	4	8.9%
Recreational Vehicle	2	4.4%
Auto Body Shop	1	2.2%
Grand Total	**45**	**100.0%**

Figure 7-4 Places Fire Fatalities Occurred in Washington in 2008.

The use of fire protection devices such as fire sprinklers and smoke detectors can greatly reduce the loss from a fire. In 2008, 25 fire fatalities occurred in Washington in buildings lacking working smoke detectors or the operation status of the device wasn't known. Other factors can contribute to fire fatalities in the homes with working smoke detectors such as not hearing the alarm due to sleeping, or the inability to escape the fire due to physical or mental impairment or disabilities. In addition, only one fire fatality occurred in a building equipped with fire sprinklers in 2008.

In conclusion, urban fires in Washington occur in the places where people feel the most safety and security, their own homes (Figure 7-5). Fire education can help reduce fires in homes and make people more aware of potentially dangerous situations. These programs can be accessed through local fire departments, community centers, and are part of some public school curriculums. With the proper use of smoke detectors and fire suppression systems loss of life due to urban fire can be greatly reduced. Human factors contributing to fires in the home can be reduced by operating heating equipment per the manufacturer's safety precautions,[43] placing a fire extinguisher in the kitchen near cooking equipment, and smoking in areas of the home where combustible material is less abundant.

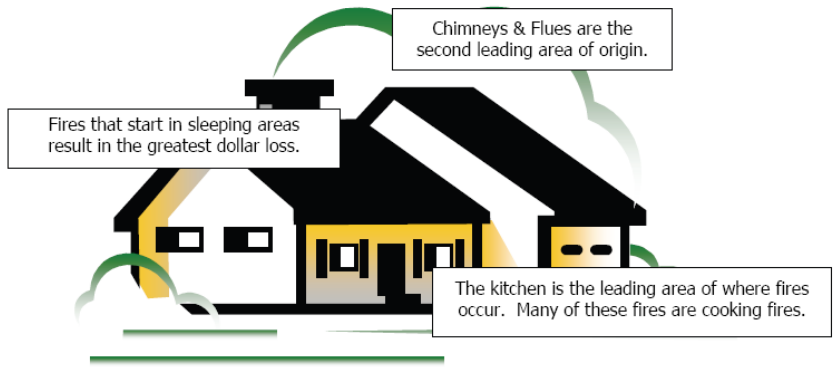

Figure 7-5 Places Where Home Fires in Washington Most Frequently Occur

Internet Resources

Washington State Fire Marshal's Fire Prevention & Safety Education
http://www.wsp.wa.gov/fire/education.htm

Washington State Fire Marshal's Office – Fire Safety Tips Calendar
http://www.wsp.wa.gov/fire/docs/prevention/calendar.pdf

Seattle Fire Department's Home Fire Safety Fact Sheet
http://www.seattle.gov/fire/pubEd/homesafety/homeFireSafety.htm

Tacoma Fire Department Fire and Life Safety Division
http://www.cityoftacoma.org/Page.aspx?hid=909

United States Fire Administration, Home Fire Prevention
http://www.usfa.dhs.gov/citizens/all_citizens/home_fire_prev/

Wildland Fire

Frequency	Annually
People	
Economy	
Environment	
Property	$100M+

Risk Level

- Frequency – One or more wildland fires occur in Washington every year.
- People – The number of lives lost to wildland fires in Washington does not meet the minimum threshold for this category.
- Economy – While the local economy where the wildland fire occurs may be affected, the affect that wildland fires have on the economy of Washington does not meet the minimum threshold for this category.
- Environment – While the damage to forest fires can be significant, the potential for 10% of a single species or habitat to be destroyed by such a fire is highly unlikely.
- Property – Past U.S., wildland fires indicate that the amount of property damage due to a wildland fire can exceed $100 million dollars.

Hazard Area Map

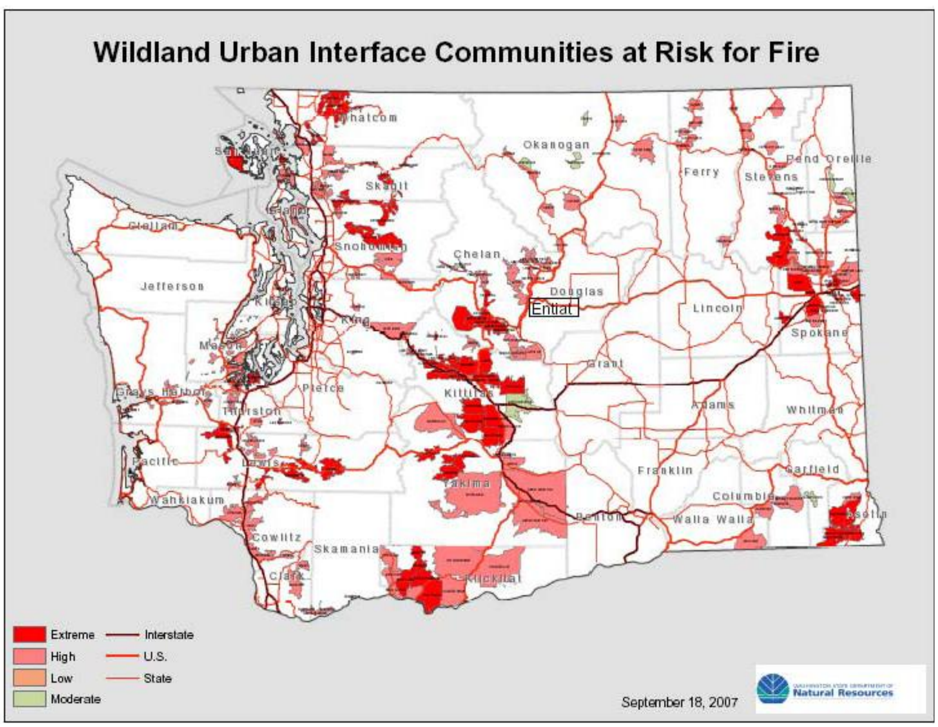

Figure 8-1 Wildland-Urban Interface Communities at Risk for Fire. (September 2007)

The hazard map represents the communities in Washington at risk to a wildland-urban interface (WUI) fire. This map was created by the Washington State Department of Natural Resources (DNR) and classifies risk of a WUI fire between moderate to extreme.

Definition

A wildland fire (Figure 8-2) is classified as "any non-structure fire that occurs in wildland. A wildfire is "an unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out".[44]

Figure 8-2 Tree line wildfire in a U.S. National Park

History

The U.S. Forest Service, Bureau of Land Management, Washington State Department of Natural Resources, and local area fire departments are responsible for the response and suppression of wildland fires in Washington. Washington's Department of Natural Resources is "the state's largest on-call fire department with 1,200 temporary and permanent employees who fight fires on about 12 million acres of private and state-owned forest lands".[45] The Bureau of Land Management manages several hundred thousand acres of public lands located mostly in the central Columbian Basin and the Northeast Highlands of Washington near the Canadian border.[46]

These agencies, along with tribal entities, U.S. Fish & Wildlife, and the fire chiefs associations for Washington and Oregon, form the Pacific Northwest Wildfire Coordinating Group (PNWCG), which provides a coordinated interagency approach to wildfire management in Oregon and Washington. The Northwest Interagency Coordination Center (NWCC) serves as the focal point for these agencies resource coordination, logistics support, aviation support, and predictive services for all state and federal agencies involved in wildland fire management and suppression in Washington and Oregon. The NWCC provides daily significant fire potential maps for the region (Figure 8-3) along with daily situation reports, briefings and large fire information summaries for local, county, and state emergency managers to keep updated on the status of these incidents.

While Washington has been fortunate not to have had a catastrophic wildfire in recent history, large fires of this kind have occurred in neighboring states, with the potential for this to occur in Washington during a given fire season. During This past October 2007, southern California experienced a series of 16 large wildfires fanned by 50 to 60 mph Santa Anna winds from the Simi Valley to the Mexico border (Figure 8-4). These fires burned over 500,000 acres, destroyed nearly 1,300 homes and caused the evacuation of over a half million people from their homes.[47] Alaska experienced its worst year for wildfires in the summer of 2004 when wildfires burned more than 5 million acres of forest.

Figure 8-3 Significant Fire Potential Map

Assessment

Washington experiences wildfires every single year. Although these fires happen every year, their impact on the state does not go without notice. Fire activity in our state has significantly been increasing over the past ten years, with not only more fires as a whole but also the fires that do occur getting larger and destroying more acres of land. The 2006 wildfire season saw almost three times the acreage burned as the 10-year average, with only slightly more fires in 2006 than the ten-year average (Figure 8-5).

Figure 8-4 Harris Fire Lights up Otay Lakes; October 23, 2007

While most wildfires in our state are caused by lightning, the second leading cause is campfires not properly attended or extinguished.[48] With proper public education on campfire safety and prevention, wildfires caused by people enjoying the outdoors in Washington could likely be reduced.

With worldwide climate change becoming an increasing concern, it is necessary to address the potential impact climate change may have on wildland fires. Many articles and scientific studies can be found that suggest wildfires have increased and will continue to increase in number and severity due to the effects of climate change. "Since 1986, longer summers have resulted in a fourfold increase of major wildfires and a six fold increase in the area of forest burned, compared to the period from 1970 to 1986".[49] It has also been noted that the "length of the active wildfire season (when fires are actually burning) in the western United States has increased by 78 days, and that the average burn duration of large fires has increased from 7.5 to 37.1 days".

ALL FIRE ACTIVITY PNW 2005 2006 and 10 YEAR AVERAGE										
Unit	Fires 2005	Acres 2005	Fires 2006	Acres 2006	10YR AVGFIRES 96-05	10YR AVGACRES 96-05	06 AS % OF 05 FIRES	06 AS % OF 05 ACRES	06 AS % OF 10YR AVG FIRES	06 AS % OF 10YR AVG ACRES
OR_BIA	139	17,142	109	5,380	107	18,280	78%	31%	102%	29%
WA_BIA	77	11,291	239	4,337	181	25,766	310%	38%	132%	17%
OR_BLM	195	35,876	357	306,170	309	96,806	183%	853%	115%	316%
WA_BLM	10	783	11	2,614	14	24,143	110%	334%	79%	11%
OR-FWS	9	451	20	4,331	13	5,717	222%	960%	150%	76%
WA_FWS	24	10,949	26	215	22	9,630	108%	2%	119%	2%
OR_NPS	0	0	8	5	15	134	#DIV/0!	#DIV/0!	54%	4%
WA_NPS	25	129	29	7,887	42	669	116%	6114%	70%	1179%
OR_USFS	691	116,240	1,422	133,594	1,114	130,284	206%	115%	128%	103%
WA_USFS	191	1,967	308	239,433	285	32,744	161%	12174%	108%	731%
OR_ORS*	837	11,605	1,103	7,693	1,030	22,474	132%	66%	107%	34%
WA_WAS*	645	3,579	1,021	48,803	833	11,415	158%	1364%	123%	428%
ALL_TOTAL	2,843	210,012	4,653	760,461	3,964	378,062	164%	362%	117%	201%
OR_TOTAL	1,871	181,314	3,019	457,173	2,588	273,696	161%	252%	117%	167%
WA_TOTAL	972	28,698	1,634	303,289	1,377	104,367	168%	1057%	119%	291%

Figure 8-5 Fire Activity for Oregon and Washington for 2005, 2006, and 10-year Average

Four critical factors have been attributed to the increase seen in wildfire activity; earlier snowmelt, higher summer temperatures (Figure 8-6), longer fire season, and an expanded vulnerable area of high-elevation forests. These factors have all been linked to the increase in overall summer temperatures that can be attributed to the effects of climate change. Although fire is an important part of a forest's lifecycle, allowing dead biomass to be recycled in a place where decomposition rates are slow on their own, "the annual damages in the western United States from wildfires have exceeded $1.0 billion in 6 of the past 15 years". This number while staggering brings home the potential impact that a large fire could have in Washington.

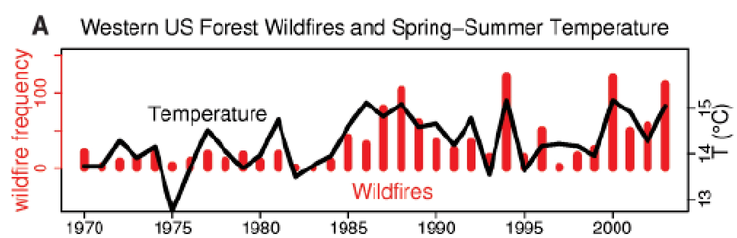

Figure 8-6 Wildfire Frequency in the Western U.S. and Spring-Summer Temperatures

With the potential for large wildfires to affect the state, federal and state agencies and organizations exist that can lessen the potential impact this hazard may have on the people, economy, environment, and property. The U.S. Geological Survey "provides tools and information by indentifying wildfire risks, ways to reduce wildfire hazards, providing real-time firefighting support, and assessing the aftermath of wildfires".[50] Washington state agencies such as the Department of Natural Resources provide burn risk information, community wildfire protection planning, and fire training and grants to help mitigate the effects of wildfires in our state. County agencies and city fire departments can also act as a local resource, providing training and education on wildfire prevention.

Internet Resources

Washington State Department of Natural Resources, Fire Information
http://www.wsp.wa.gov/fire/firemars.htm

National Wildfire Incident Information
www.inciweb.org/1/a/10/

Northwest Interagency Coordinating Center
http://nwccweb.us/

Geospatial Multi-Agency Coordination Wildland Fire Support
www.geomac.gov/

National Interagency Fire Center
www.nifc.gov/fire_info/nfn.htm

Pacific Northwest Region USDA Forest Service Fire & Aviation Management
www.fs.fed.us/r6/fire/

U.S. Geological Survey- Wildfire Information
http://www.usgs.gov/hazards/wildfires/

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Floods

Frequency	Annually
People	1 -5,000
Economy	1-2% GDP
Environment	
Property	$100-500M

Risk Level

- Frequency – Flooding occurs in Washington on an annual basis.
- People – Several U.S. floods have claimed the lives of over 1,000 people.
- Economy – During a flooding event the local economy can suffer severely, which in turn can result in an impact to the overall economy in the state of Washington.
- Environment – Although the environment can suffer irreversible damage due to a flooding event, the type of damage does not meet the threshold for this category.
- Property – Disaster assistance for the last major flood in Washington reached an estimated $72.5 million dollars. With continued growth of industry and towns in and around these areas, property damage is estimated to rise with each subsequent flood.

Hazard Area Map

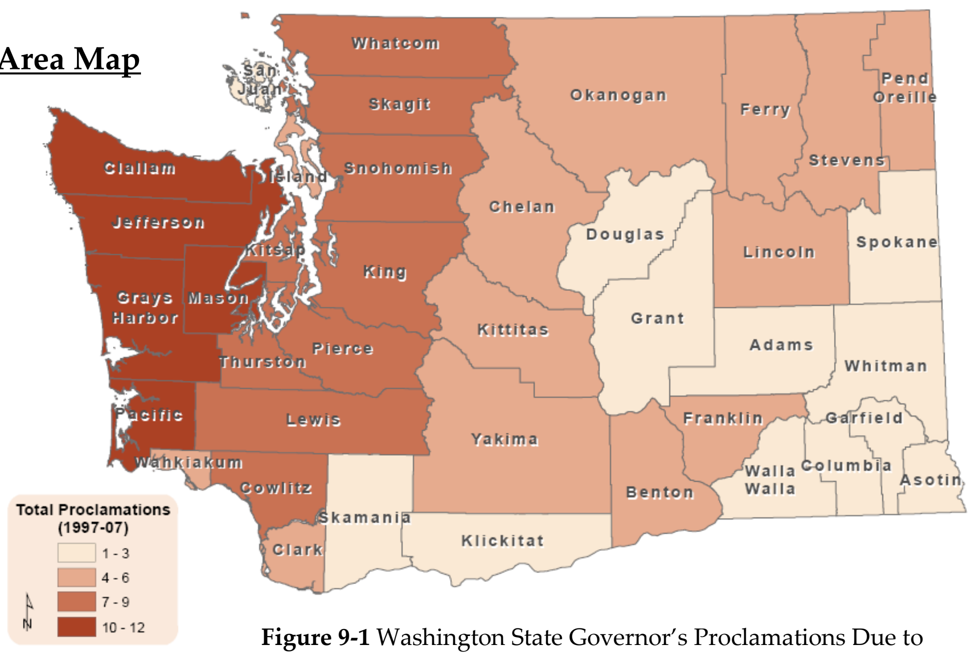


Figure 9-1 Washington State Governor's Proclamations Due to Flooding, 1997-2007.

The hazard area map of Washington depicts the number of emergency declarations for each county due to flooding. Governor's Emergency Proclamations from 1997 to 2007 were gathered, the number of declarations for each county was compiled for each year and then all declarations were totaled to generate the above map.

Definition

A flood is an overflow of an expanse of water that submerges land that was previously dry. It is usually due to the volume of water within a body of water, such as a river or lake, exceeding the total capacity of the body, and as a result, some of the water flows or sits outside of the normal perimeter of the body. Types of floods that occur in Washington include riverine, coastal, flash and tidal flooding. Riverine and flash floods result from rivers and streams, while coastal and tidal flooding occur along the Pacific Ocean shoreline of Washington because of severe sea storms and or tsunamis. Flooding can also occur because of dams or levee failure, but these types of floods will be addressed further in another section.

History

Floods are the most chronic and costly natural hazard in the United States (Figure 9-2), causing an average of 99 fatalities and $5 billion damage each year." Despite advances in flood science and implementation of Federal hazard-reduction policies, damage from flooding continues to escalate".[51] "In the United States, about 3,800 towns and cities of more than 2,500 inhabitants are on floodplains".

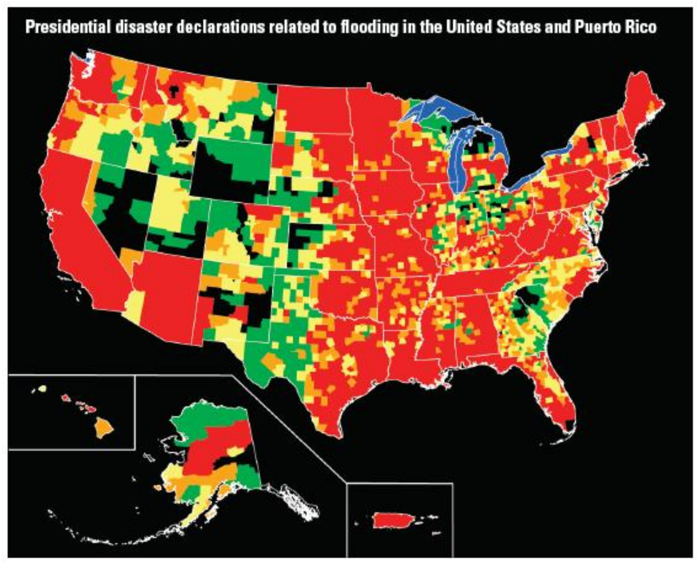


Figure 9-2 Presidential Disaster Declarations Related to Flooding in the U.S. Green areas represent one declaration, yellow areas represent two declarations, orange areas represent three declarations and red areas represent four or more declarations. Declarations were gathered for the map from June 1, 1965 to June 1, 2003. (Black areas represent zero declarations)

The late summer of 2005, showed us the power and destruction of a flood with the flooding caused by Hurricane Katrina. This event resulted in more than $200 billion in losses and constituted the costliest natural disaster in U.S. history.[52] Although this type of extreme event does not happen every year, "in typical years flooding causes billions of dollars in damages and threatens lives and property in every state". In fact, the average annual U.S. flood losses between 1994 and 2004 were more than $2.4 billion.[53]

The loss of life to floods during the past half-century has declined, mostly because of improved warning systems, economic losses have continued to rise due to increased urbanization and coastal development. Of the fatalities that do result from flooding, "more than half of all fatalities are auto related and usually the result of drivers misjudging the depth of water on a [flooded] road and the force of [the] moving water".

"Fifteen years ago, a disastrous flood swept through the Midwest, causing a estimated $20 billion in flood damage, nearly 50 deaths and untold trauma to the hundreds of thousands" of people affected.[54] The Midwest flood of 1993 resulted in the worst river-related flood in the history of the U.S.

Internationally, flooding has also resulted in great losses of life and destruction of property and infrastructure. "Every Dutch citizen who is old enough has a story to tell about the storm surge that burst through poorly maintained dikes [in 1953], killing 2,000 people. The Misery of 1953 is remembered alongside the storms of other centuries -- the St. Elizabeth flood of 1421, the All Saints' Day flood of 1570".[55] One of the most prone areas to flooding in Asia is China's Yellow River. This river is prone to flooding because of its broad expanse of plain that lies around it and the high silt content that gives the river its yellow tint and its name. The 1931 flooding event of this river resulted in the largest death toll from flooding at an estimated 1 million to 3 million people.[56] The history of flooding on this river has prompted the Chinese government to embark on a program of building dams for flood control along the Yellow River.

Assessment

"Damaging floods result when the volume of river flow exceeds levels of flood preparedness, either because flow is greater or longer than expected or because of incomplete understanding of local hazards. Consequently, a primary means of reducing floods hazards is by better understanding the magnitude and likelihood of large flows. The data underlying most studies of flood magnitude and frequency in the United States [and Washington] are records of U.S. Geological Survey (USGS) stream flow gauges for which the last 110 years have been collecting stream flow data at more than 23,000 locations (although not all stream flow gauging stations have operated continuously). In addition to the USGS Stream Gauge Network, the National Weather Service, have river forecast offices in Washington that monitor the USGS stream gauges and other climate factors to generate and disseminate flooding forecasts to help citizens, counties and cities prepare for a future flooding event.

Flooding potential dominates the winter and early spring due to melting snow and rainy weather. Many rivers in Washington flood every two to five years; these include rivers flowing off the west slopes of the Cascades (Cowlitz, Green, Cedar, Snoqualmie, Skykomish, Snohomish, Stillaguamish, Skagit and Nooksack Rivers), out of the Olympic Mountains (Satsop, Elwha, and Skokomish Rivers) and those rivers flowing out of the hills of Southwest (Chehalis, Naselle and Willapa Rivers). Several rivers in Eastern

Washington also floods every two to five years; these include the Spokane, Okanogan, Methow, Yakima, Walla Walla and Klickitat Rivers. Flooding on rivers east of the Cascades is generally the result of periods of heavy rainfall, mild temperatures and from spring runoff of the mountain snow pack. Counties located on the Pacific Coast of Washington and those inland coastal counties along with counties located at the mouth of the Columbia River are also susceptible to wind and barometric tide flooding.

Much of the recent development in this State occurs in or near flood plains. Development in these areas increases the risk of floods and flood damage in two ways. First, development in or near a flood plain adds people and structures to an area previously uninhabited. Second, new construction tends to alter the normal course that water travels during a flood, making water travel over now impermeable surfaces, such as roads and house roofs, to places previously not in harm's way.

Flood plains or areas at risk from flooding make up approximately 7.5% of the state's total land area. These areas contain an estimated 100,000 households, with the number growing every year. The homes and the citizens that live in these areas are all at risk from a flood. FEMA administers the National Flood Insurance Program (NFIP); the only government insurance program that covers a natural disaster, and can help citizens at risk of flooding by providing some financial reassurance if such an event should happen to them. According to the National Flood Insurance Program, a home with a 30-year mortgage has a 26% chance of being damaged by a flood in comparison to a 9% chance of being damaged by a fire in the same period.

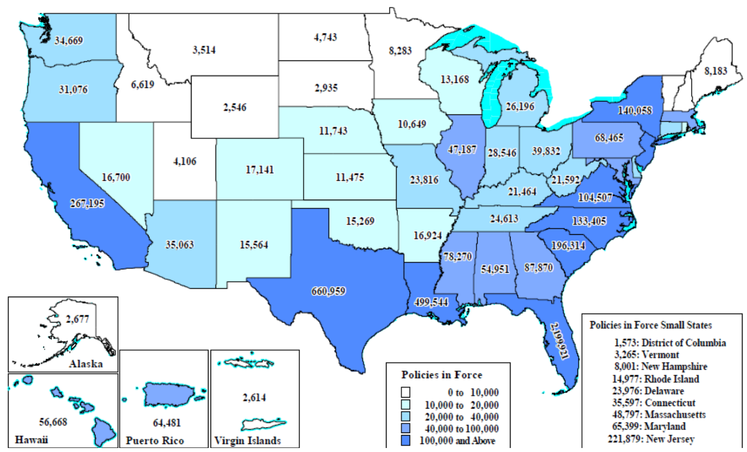


Figure 9-3 Flood Insurance Policies in force in the U.S. as of September 30, 2007

While the NFIP can provide some peace of mind to citizens in these hazard areas, it should not be a substitute for public education, mitigation, and disaster preparedness efforts, but rather as an addition to these programs. Currently, there are 291 communities in Washington participating in the National Flood Insurance Program.[57] Community participation in this program, grants citizens the opportunity to purchase flood insurance from the NFIP. As of September 2007, there were 34,669 flood insurance policies in force in Washington (Figure 9-3).

A 2002 study published in the journal *Nature* reviewed data on 100-year (1% annual probability) floods in the last century in the 29 major river basins in the World.[58] Models produced in this study suggested that " instead of a 100-year flood occurring once every 100 years, which is what you would expect, the risk [in response to climate change] will increase in the 21st century to somewhere between 3 to 6 chances in 100" years).[59] Coastal flooding is also a concern in Washington with the rise in sea level because of global ocean warming. "The United Nation's Intergovernmental Panel on Climate Change (IPCC) reports that from 1993 to 2003, global sea level rose about 3 millimeters (approximately 0.12 inches) each year (Figure 9-4), and approximately half of that increase is attributed to the ocean expanding as it warms (Figure 9-5)".[60] While a sea rise of a few millimeters may seem insignificant, Carol Auer, an Oceanographer with the National Oceanic and Atmospheric Administration (NOAA) says, "A half-inch of vertical sea level rise translates to about three feet of land lost on a sandy open coast, due to long tern erosion. Moreover, even a slightly higher sea level can cause more dramatic deltas and estuary tides. Rising sea levels also make coastal areas more vulnerable to storm surges, and in turn, to flooding".

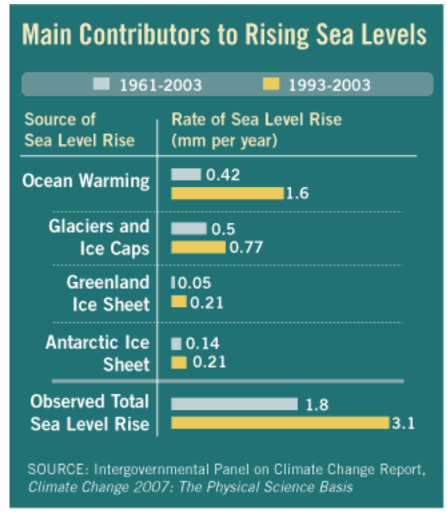


Figure 9-4 Main Contributors to Rising Sea Level Change. The global average sea level rose at a rate of 1.8 millimeters per year between 1961 and 2003. That rate increased starting in 1993, with the sea level rising about 3.1 millimeters per year. The major contributors to the rising ocean is the expansion of water as the ocean absorbs heat from the atmosphere, and melt water

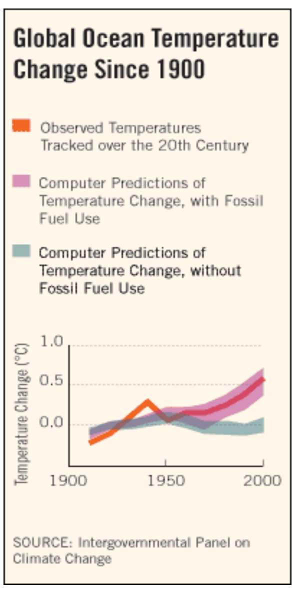


Figure 9-5 Global Ocean Temperature Change Since 1900

Some suggest that there is a "better way to deal with floods: the "soft path" to flood risk management".[61] The "soft path" strategy to flood management takes into account the fact that floods will happen and to learn to deal with them the best way possible. "This strategy is also based on an understanding that flooding is essential for the health of riverine ecosystems. A "soft path" approach means taking measures to reduce the speed, size and duration of floods by restoring meanders and wetlands…." This approach "also means doing all we can to get out of floods' destructive path with improved warning and evacuation measures. Such practices are already in use in some parts of the United States and around the world". "Improving our ability to cope with floods requires adopting a more sophisticated set of techniques. The "soft path" of flood management should be a core part of efforts to adapt to a changing climate". Such a strategy may reduce deaths due to flooding and could result in much healthier rivers and streams.

According to the FEMA, "everyone lives in a flood zone".[62] Whether you live in a low, moderate, or high-risk area is the question that needs to be determined. In fact, last year (2007)"one-third of all claims paid by the NFIP were for polices in low-risk communities". Flooding in these low-risk areas can likely be attributed to increased development in areas near flood plains that result in increases in storm water run-off. Due to increases in impermeable surfaces (due to development in these areas), water now has nowhere to go but into homes and businesses that were once unlikely to be affected by flooding.

Since buildable land can be limited in areas, it is unrealistic to limit development in areas near and on the flood plain. Local ordinances can regulate planning, construction, operation, and improvements in these areas to avoid adversely affecting a nearby stream or body of water. Developments in flood plains should look to non-structures, such as parks, golf courses, playfields, and farms, which have the least potential for severe damage and can work to capture some floodwaters before they reach businesses and homes.

In conclusion, flood disaster preparedness, mitigation, public education and participation in the NFIP are all keys components to managing flood risk in Washington. By utilizing flood hazard products and forecasts produced by federal entities such as the National Weather Service, counties and cities can help manage the risk of floods for the people, economy, environment, and property of Washington.

Internet Resources

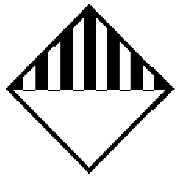
United States Geological Survey (USGS), National Hazards-Floods
http://www.usgs.gov/hazards/floods/

Washington Department of Ecology, Flood Site
http://www.ecy.wa.gov/programs/sea/floods/index.html

Federal Emergency Management Agency, Floodplain Management
http://www.fema.gov/plan/prevent/floodplain/index.shtm

Federal Emergency Management Agency, National Insurance Program – Flood Hazard Mapping
http://www.fema.gov/plan/prevent/fhm/index.shtm

Incident, Chemical



Frequency	Annually
People	0-1,000
Economy	
Environment	
Property	

Risk Level

- Frequency – Hazardous materials incidents occur annually in Washington.
- According to the Washington State Alert and Warning Center (AWAC), State Emergency Operations Officers responded to 2,354 hazardous materials (HAZMAT) incidents in 2007.
- People – Due to the transportation and location of chemical manufacturing and chemical storage facilities in highly populated counties within the state, the likelihood that up to 1,000 people could be affected by such an incident seems probable.
- Economy – When a chemical incident occurs, the effect to the economy of Washington does not reach the amount set as a minimum threshold for this category.
- Environment: Although the damage to the environment can be significant in a chemically related incident, the likely effect is not thought to reach the minimum threshold set for this category.
- Property – The effect on the property in Washington by a chemical incident does not meet the minimum threshold for this category.

Hazard Area Map

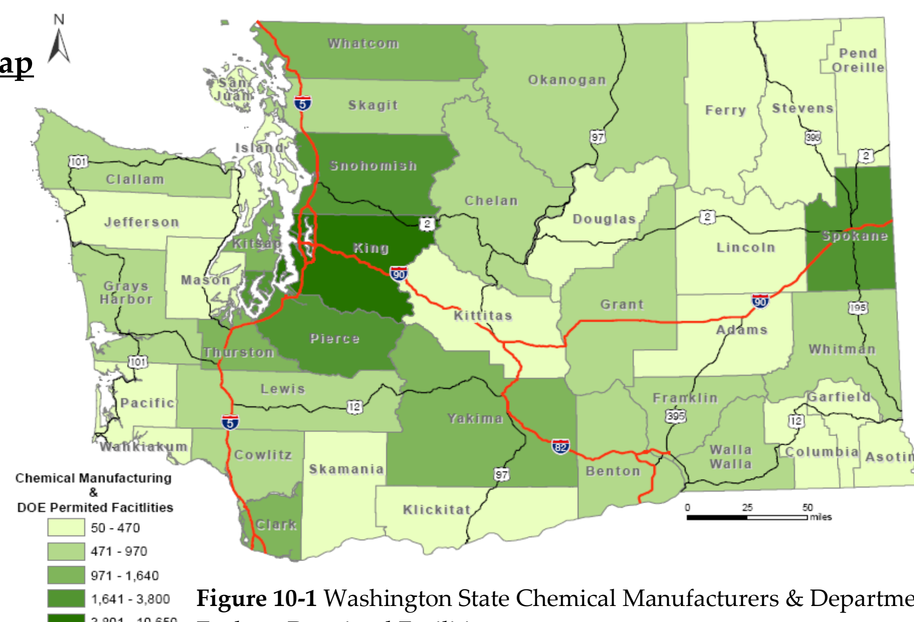


Figure 10-1 Washington State Chemical Manufacturers & Department of Ecology Permitted Facilities

The hazard area map (Figure 10-1) indicates the number of chemical manufacturers and Washington State Department of Ecology regulated facilities, by county. Chemical manufacturers for each county were derived from the 2005 Homeland Security Infrastructure Protection (HSIP) data and the regulated facilities for each county were derived from the Washington State Department of Ecology's website. Regulated facilities for the Department of Ecology consist of state cleanup sites, federal superfund sites, hazardous waste generators, solid waste facilities, underground storage tanks, and dairies. The Department's data used for this map did not distinguish the types of regulated facilities and thus can only be used as an approximation for regulated facilities in a county.

From the map, the highest concentration of chemical manufacturers and regulated facilities exist in western Washington's Puget Sound area, with the exception of Spokane County. Also of note is the transportation network that links the counties in the State. This network makes it possible for chemical hazards to travel between counties and could potentially expose the people, economy, environment, and property of counties containing less chemical facilities to chemical incidents from material originating in other counties in the state.

Definition

Chemical incidents involve the unintentional or intentional release of hazardous materials, which because of their physical, biological, or chemical makeup, pose a threat to the life, health, environment, or property around them. A release may occur by spilling, leaking, emitting vapors, or any other process that enables the material to escape its normal holding vessel, enter the environment, and create a potential hazard. This hazard can be classified as explosive, flammable, combustible, corrosive, reactive, poisonous, a biological agent, or radioactive.

History

Due to the harm caused by major oil spills in the late 1980s and early 1990s, the federal and state Legislature enacted laws to protect the health of the environment and people from such spills.

National and international incidents involving chemicals and other hazardous materials tend to involve materials with radioactive properties but there are a few exceptions in which people, the environment, the economy, and property, have been affected by chemicals or hazardous materials incidents. One of the most well known chemical disasters happened in 1984 in Bhopal, India at a Union Carbide insecticide plant. Water was mistakenly introduced into a holding tank of methyl isocyanate liquid, causing a runaway chemical reaction to occur which created intense pressure in the tank causing it to rupture. The resulting gases from this reaction leaked out of holding tank at the plant, resulted in the deaths of 10,000 people, and injured another 150,000. "Less than a year later, a Union Carbide plant that produced methyl isocyanate in Institute, West Virginia, leaked a toxic cloud (of a different chemical) in the Kanawha Valley (which injured 6 plant employees and 129 community members). While the West Virginia incident was not another tragedy, it was a reminder that an accident such as the one that occurred in Bhopal could happen in the United States".[63]

Figure 10-2 Hazardous material spill as a result of a train derailment near Milligan, Florida.

Senate hearings and media attention stemming from the West Virginia incident led to the enactment of the Emergency Planning and Community Right to Know Act of 1986 (EPCRA), which requires companies to provide information about their potentially toxic and harmful chemicals. Fortunately, Washington has not been the site of a major chemical incident, but had a narrow escape in February of 2007 when 900 to 1300 pounds of chlorine gas was released at the Pioneer America's chlorine production plant located in Tacoma's tide flats. Twenty-five people suffered minor symptoms due to the exposure of the gas, but because the incident occurred during the night shift, the more than 10,000 people who work in this area during the day were kept out of harm's way.[64 65]

"Although the major chemical accidents seem most threatening because they often kill people outright, it is the smaller, more routine accidents and spills that affect most people. Some of the most common spills involve tanker trucks and railroad tankers containing gasoline, chlorine, acids, or other industrial chemicals," during the transportation of hazardous materials. In 1983, hazardous material spills from 4,829 highway and 851 railroad accidents resulted in eight deaths, 1919 injuries, with damages exceeding $110 million dollars (1983 dollars). "The National Environmental Law Center reported that 34,500 accidents involving toxic chemicals were reported to the Environmental Protection Agency's Emergency Response and Notification System between 1988 and 1992, meaning that on average, a toxic chemical accident was reported 19 times a day in the United States".

To help emergency responders become aware of the possible chemicals they may encounter at the locations of an incident the U.S. Department of Transportation has established a hazardous materials placard system (Figure 10-3). Railroad cars and trucks carrying chemicals or hazardous wastes must display a diamond-shaped placard which includes a material identification number, a hazard class number and symbol, which identifies the material as a flammable liquid or solid, non-flammable or flammable gas, explosive, corrosive, toxic, oxidizer or organic peroxide, environmentally hazardous, or radioactive material.

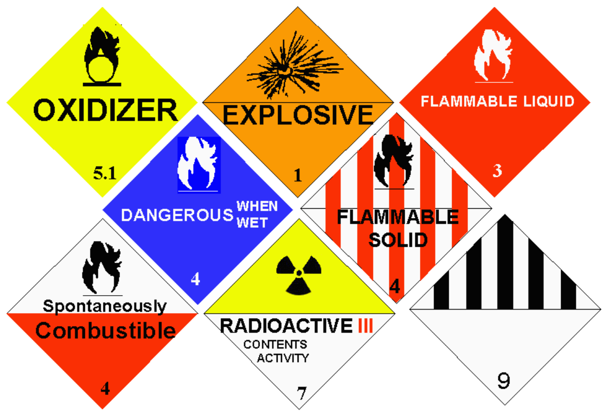


Figure 10-3 U.S. Department of Transportation Placards

<u>Specific Washington Laws Relating to Hazardous Materials:</u>

- RCW 90.56 – *Oil and Hazardous Substance Spill Prevention and Response*
- RCW 88.46 – *Vessel Oil Spill Prevention and Response*
- RCW 90.48 – *Water Pollution Control*
- RCW 88.40 – *Transport of Petroleum Products – Financial Responsibility*
- RCW 70.105 – *Hazardous Waste Management*
- RCW 70.105D – *Hazardous Waste Cleanup – Model Toxics Control Act*

Assessment

Manufacturing, storing, and transporting chemicals all pose the risk of accidents. The impacts of these accidents can sometimes be deadly, but can also cause harm or destruction of the environment and property. Many, if not most, of the products that we use everyday are made from chemicals and thousands of chemicals are used by the manufacturing industries in the creation if these products. "Of the more than forty-thousand chemicals in commercial use, most are subject to accidental spills or releases. Chemicals spills and accidents range from small to large and can occur anywhere chemicals are found, from oil drilling rigs to factories, tanker trucks and fifty-five gallon drums" and as well as your home.

"Over 20 billion gallons of oil and hazardous chemicals are transported through Washington each year by ship, barge, pipeline, rail, and road. Accidents, equipment failure, and human error can all lead to unintended and potentially disastrous consequences. Oil and chemical spills can threaten some of the most productive and valuable ecosystems in the world. These incidents can kill fish, birds, and marine animals and contaminate beaches and shellfish. All spills whether on land or water can threaten public health, safety, the environment, and ultimately damage the state's economy and quality of life."[66] In addition to industrial and household chemicals, Washington has experienced instances of clandestine drug lab chemical dumping in urban and rural environments (Figure 10-4). Although these instances have recently been on the decline, Washington's Department of Ecology responded to over 230 instances of illegal dumping of chemicals from clandestine drugs labs manufacturing methamphetamine in 2007.[67]

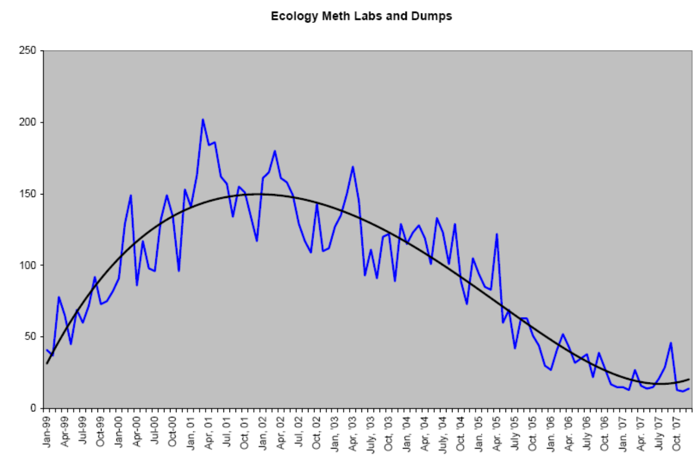


Figure 10-4 Washington department of Ecology Methamphetamine Manufacturing Labs and Illegal Chemical Dumps, January 1999 to October 2007

The Washington State Hazardous Materials Program consists of several agencies, each responsible for specific elements of this program. A number of strategies have evolved to limit risk, respond to, and recover from chemical incidents in the State. A comprehensive system of laws, regulations, and resources are in place to provide for technical assistance, environmental compliance, and emergency management for chemical incidents within the state. The Department of Ecology is tasked with the response to and cleanup of oil and hazardous material spills and the cleanup of methamphetamine drug labs. Oil spills, chemical spills, and methamphetamine labs are responded to and cleaned up rapidly to protect human health, natural resources, and property. Ecology's spill response capability is maintained 24-hours-a-day and 7-days-a-week throughout the State, with oil spills being responded to no later than 24-hours from the time that they are reported. Serious spills receive a rapid response from the Department of Ecology, which on average responds to over 3,800 spill reports annually.

Though quite difficult to determine the risk of a chemical incident without knowing the type and amount of chemical involved, and where the location of the incident will be, one can say that the some of the overall risk associated with chemical incidents is related to the area in which one travels or lives. As displayed in the hazard map (Figure 10-1), western portions of Washington State around Puget Sound have higher concentrations of permitted chemical facilities and chemical manufacturing sites then the other areas of the state. For chemical incidents from permitted facilities and chemical manufacturers, the risk of potential chemical incidents can be considered higher in these counties than others. Although risk of fixed permitted and manufacturing facilities can be deemed greater in these counties due solely to the quantity of these types of facilities located within each county, most chemicals travel some distance within our State's waterways, interstates, and highways to their intended destination making other counties also at potential risk for chemical incidents.

Chemical accidents and spills can be devastating to people, the environment, the economy, and property. The best way to reduce the harm caused by chemical accidents is to design manufacturing plants with better safety controls and to use, manufacture and store less toxic compounds. Chemists and engineers are currently pursuing this field known as "green chemistry", but until the science exists to replace toxic chemicals with less harmful substitutes, the emergency response procedures and the rules and regulations that govern hazardous material use, transport, and disposal can help lessen the human health and environmental effects that result from a chemical incident.

Internet Resources

U.S. Chemical Safety and Hazards Investigation Board Chemical Incidents Report Center
http://www.csb.gov/index.cfm?folder=circ&page=index

King County Hazardous Waste Management Program
www.govlink.org/hazwaste/index.cfm

Washington State Patrol, Office of the State Fire Marshal,
Hazardous Materials Training Unit
www.wsp.wa.gov/fire/hazmat.htm

Federal Emergency Management Agency (FEMA), Hazardous Materials Incidents
www.fema.gov/business/guide/section3b.shtm

Incident, Radiological

Frequency	50+yrs
People	10,000 – 50,000
Economy	1-2%GDP
Environment	
Property	$100-500M

Risk Level

- Frequency – There has not been a significant release of radiological material in Washington in the past 50 years.
- People – If a release of radiological material were to occur at a fixed radiological facility or of material being transported in large enough quantity, there is potential for this release to affect between 10,000 and 50,000 people depending on the population size of the surrounding area.
- Economy – In the event of a radiological incident, the economy of Washington State is felt to be affected by at least a drop of 1 to 2% of state gross domestic product (GDP) due to fallout from the potential radiological contamination and other factors that could come about due to such an incident.
- Environment – Although there is potential for radiological contamination of the environment due to a release of radiological material, the likelihood that such a release could eradicate 10% of a single species or habitat is felt to be rather minimal and as such, this type of incident does not meet the minimum threshold for this category.
- Property – A worst-case scenario release of radiological material could potentially contaminate a large amount of property within the State, both residential and agricultural. At minimum, the total dollar value of this property could be valued between $100 and $500 million dollars.

Hazard Area Map

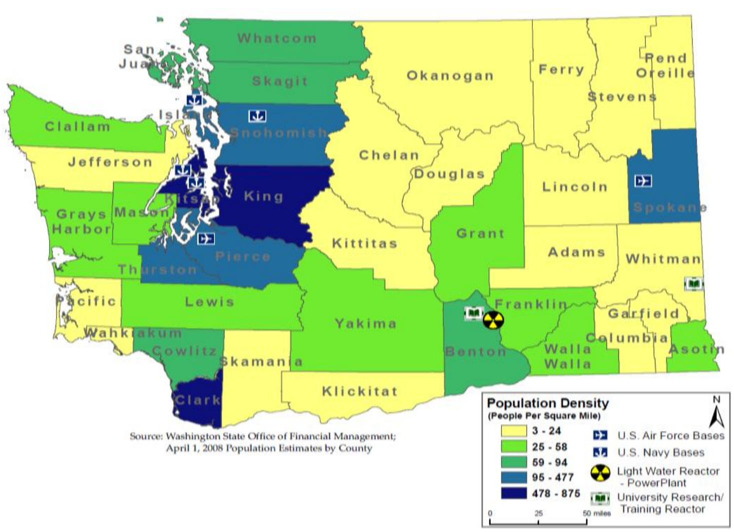


Figure 11-1 Population Density and Potential Locations of Radiological Material

The hazard map (Figure 11-1) indicates population density for each of Washington State's 39 counties in addition to places that may potentially contain radiological material. The areas indicated on the map include U.S. Navy bases, U.S. Air Force bases, university and research training reactors, the Columbia Generating Station power plant reactor located in Benton County that is operated by Energy Northwest, and the Hanford-Department of Energy radiological waste storage facility. The locations included on the map are by no means to be considered the only sources of radiological material in the State. Other sources of radiological material may be located at hospitals, medical research facilities, and hazardous waste disposal companies. In addition to fixed facilities that store and use radiological material this type of material can also be transported by rail, air, and truck. Although difficult to anticipate where a radiological incident may occur, a potential incident is more likely to occur along the major transportation corridors used to transport this type of material or at sites that utilize and or store radiological material.

Definition

A radiological incident involves the release and potential exposure of radiological material to the people, environment, and or property in Washington.

More than 100 years ago, scientists discovered that many elements commonly found on Earth occur in different configurations at the most basic atomic level. These various configurations, called isotopes, have identical chemical properties, but different physical properties. In particular, some isotopes, known as radioisotopes, are radioactive, meaning they emit energy in several different forms. This energy emission is known as radiation.

Radiation comes in two basic physical forms. One form of radiation is known as electromagnetic radiation (non-ionizing radiation) such as x-rays, radar, and radio waves. The other form of radiation, known as particle radiation or ionizing radiation, consists of small fast-moving particles that have both mass and energy. When ionizing radiation passes through material, it deposits enough energy to break molecular bonds and displace or remove electrons from atoms. This electron replacement creates two electrically charged particles (ions), which may cause changes in the cells of plants, animals, and people. Some ionizing radiation is used for beneficial uses such as in smoke detectors, to treat cancer and sterilize medical equipment. If used improperly ionizing radiation can be extremely harmful.

The U.S. Regulatory Commission strictly regulates commercial and institutional uses of nuclear materials, including the following five major types of ionizing radiation (Figure 11-2):

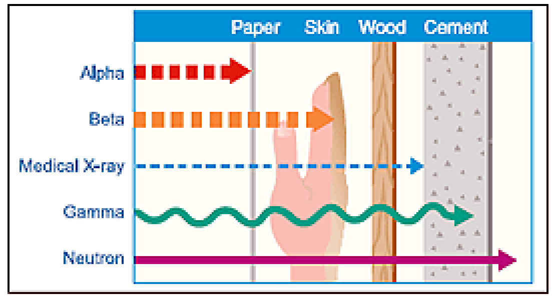


Figure 11-2 The Five Types of Ionizing Radiation. This figure shows the five types of ionizing radiation and their ability to penetrate a variety of materials.

- **Alpha Particles** – Charged particles, which are emitted from naturally occurring materials (such as uranium, thorium, and radium) and man-made elements (such as plutonium and americium), have a very limited ability to penetrate other materials.
- **Beta Particles** – Charged particles similar to electrons, which are emitted from naturally occurring materials (such as strontium-90).Have a better ability to penetrate other materials, but like alpha particles, they do not make things radioactive.
- **Gamma Rays and X-Rays** – Consist of high-energy waves that can travel great distances at the speed of light and generally have a great ability to penetrate other materials. For this reason, they are generally used to treat cancer (cobalt-60) and sterilize medical instruments and to provide static images of body parts, such as teeth and bones. Like alpha and beta particles, gamma rays and x-rays do not make things radioactive.
- **Neutrons** – High-speed nuclear particles that have an exceptional ability to penetrate other materials. Neutrons are the only type of ionizing radiation that can make objects radioactive. Because of their exceptional ability to penetrate other materials, neutrons can travel great distances in air and require very thick hydrogen-containing materials (such as concrete or water) to block them. Neutron radiation primarily occurs inside a nuclear reactor, where many feet of water provide effective shielding.

History

The most catastrophic radiological incident to occur in history took place on April 26, 1986 in the former Soviet Union. This accident took place at the Unit 4 nuclear power station in Chernobyl, Ukraine. The accident was caused by a sudden surge of power, which destroyed the reactor and released massive amounts of radiological material into the environment. After the accident, access to the area in a 30-kilometer (18-mile) radius around the plant was closed off except for persons requiring official access to the plant to deal with the accident and contamination. The population evacuated from the most heavily contaminated areas numbered approximately 116,000 in 1986 and another 230,000 people in subsequent years.[68]

The Chernobyl accident caused many severe radiation effects almost immediately. Among the approximately 600 plant workers present at the time of the accident, 2 died within hours of the reactor explosion and 134 received high doses of radiation and suffered from acute radiation sickness. Of these, 28 workers died in the first four months after the accident. This accident also resulted in widespread contamination in areas of Belarus, the Russian Federation, and Ukraine, areas, which are home to millions of residents. The health of these residents has been monitored since 1986, and to date there is no strong evidence for radiation-induced increases of leukemia or solid cancer (other than thyroid cancer).

An exception is a large number of children and adolescents who in 1986 received substantial radiation doses in the thyroid after drinking milk contaminated with radioactive iodine. To date, about 4,000 thyroid cancer cases have been detected among these children. Although 99% of these children have been successfully treated, 9 children and adolescents among the three countries affected died from thyroid cancer. Apart from the increase in thyroid cancer after childhood exposure, no increase in overall cancer and non-cancer diseases have been observed that can be attributed to the Chernobyl accident and exposure to radiation. It is estimated that approximately 4,000 radiation-related cancer deaths may eventually be attributed to the Chernobyl accident over the lifetime of the 200,000 emergency workers, 116,000 evacuees, and 270,000 residents living in the most contaminated areas.

The accident at the Three Mile Island Unit 2 (TMI-2) nuclear power plant near Middletown, Pennsylvania, on March 28, 1979, was the most serious in U.S. commercial nuclear power plant operating history, even though it led to no deaths or injuries to plant workers or members of the nearby community. The sequence of certain events – equipment malfunctions, design related problems, and worker errors – led to the partial meltdown of the TMI-2 reactor core and to a small off-site release of radioactive materials.

Detailed studies were conducted on the radiological consequences of the incident by the U.S. Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), the Department of Health and Human Services (DHHS), the Department of Energy (DOE), and the State of Pennsylvania. Estimates are that the average dose to the approximately 2 million people living in the area was about 1 millirem (8 millirem is the average exposure for a full set of chest x-rays) (Figure 11-3). Compared to the natural radioactive background dose of about 100-125 millirems per year for the area, the collective dose to the community from this accident were very small. In the following months, questions were raised about the possible adverse effects of radiation release to human, animal, and plant life in the area of which none could be directly correlated to the accident. Comprehensive investigations and assessments following the Three Mile Island Incident have concluded that in spite of serious damage to the reactor, most of the radiation was contained and that the actual release had negligible effects on the physical health of individuals or the environment. [69]

In spite of the fact that the Three Mile Island Incident caused no deaths or injuries and negligible release of radiological material, it led to sweeping changes involving emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations. These changes, according to the NRC, have resulted in the enhancement of the overall safety of nuclear power plant operation.

Measuring Radiation's Effects

Activity	Millirems
Typical yearly dose, all sources	360.00
Full set of dental X-rays	40.00
Chest X-ray	8.00
Flying round-trip from D.C. To Los Angeles	5.00
Living outside nuclear power plant for a year	0.10

Health risk	Expected life lost
Smoking a pack of cigarettes a day	6 years
Being 15 percent overweight	2 years
Working in construction	227 days
Working in nuclear plant (1,000 mrem/yr)	51 days
Typical annual background radiation dose (360 mrem/yr)	18 days

Figure 11-3 Radiation Exposure Levels and Effects

Assessment

The *Integrated Fixed Facility Radiological and Chemical Protection Plan* (IFFRCPP) maintained by the Washington State Emergency Management Division provides guidance to state agencies in the event of a chemical (see Umatilla Chemical Depot Hazard Assessment) or radiological material incident. For radiological incidents, this plan covers incidents that may occur at the DOE-Hanford radiological waste storage facility, Energy Northwest's nuclear power plant, and for the U.S. Navy bases that are located in and around the Puget Sound region. This plan includes emergency and notification procedures, emergency planning zones and protective action guidelines for both the CGS and Hanford-DOE areas.

The establishment of Emergency Planning Zones is not applicable to naval nuclear propulsion plants due to their difference in design and operation when compared to commercial nuclear power plants. The U.S. Navy's Naval Propulsion Program has designated Areas of Planning Attention (APA) to assist state and local authorities in assessing the need for preplanning near naval bases or shipyards where nuclear powered vessels are normally berthed. These APAs extend 0.5 miles around every location where nuclear powered vessels are berthed. The 0.5-mile distance is based on detailed, conservative analysis of worst case, but credible scenarios for a radiological release with the actual radius of the impacted areas downwind most likely being much smaller. For Naval Base Kitsap-Bremerton and Naval Station Everett, only a few city blocks are within the 0.5-mile APA radius. For Naval Base Kitsap-Bangor, the Area of Planning Attention's 0.5 miles radius is completely within the boundaries of the base.[70]

The Radioactive Materials Section within the Washington State Department of Health is responsible for the regulation of radioactive materials throughout the state. A specific license, issued by this agency, is required to receive, possess, use, transfer, or acquire most radioactive materials. Licensees and registrants are periodically inspected for regulation compliance, material use and handling, personnel training, security, transportation, and other important factors that correspond with the possession of radiological materials.[71]

Washington is vulnerable to a release of radiological material simply because such material exists in this state. The overall risk of such an occurrence has been dramatically lessened due to the regulation of radiological material and the radiological incident plans and procedures in place at various state agencies, which serve as the guidelines to facilitate a swift response to such an incident and to lessen the overall exposure of radiological material to the public.

Internet Resources

The United States Nuclear Regulatory Commission
www.nrc.gov/

Washington State Department of Health, Division of Environmental Heath-Office of Radiation Protection
www.doh.wa.gov/ehp/rp/rp-regs.htm

U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration
www.phmsa.dot.gov/hazmat

Washington State Department of Ecology, Nuclear Waste Program
www.ecy.wa.gov/programs/nwp/index.html

Frequency	Annually

Infestation

People	
Economy	1-2% GDP
Environment	
Property	$100M

Risk Level

- Frequency – Infestations of invasive species of animals and plants are an ongoing occurrence in Washington and has therefore been given an annual rating up above.
- People – People are not usually directly affected by an infestation of an animal or plant in that lives are not generally lost in this type of event.
- Economy – Agriculture is a major contributor to the State's Gross Domestic Product (GDP), therefore if an infestation of a plant or animal happened that directly affected the agricultural crops of the State, the economy could be adversely affected.
- Environment – Although damage to the environment can be severe in an infestation event, the likelihood of an infestation eradicating 10% of a single species or 10% of a habitat is thought to be unlikely.
- Property – Agricultural lands, state and federal forests, and homes can all be affected by an infestation event.

Hazard Area Map

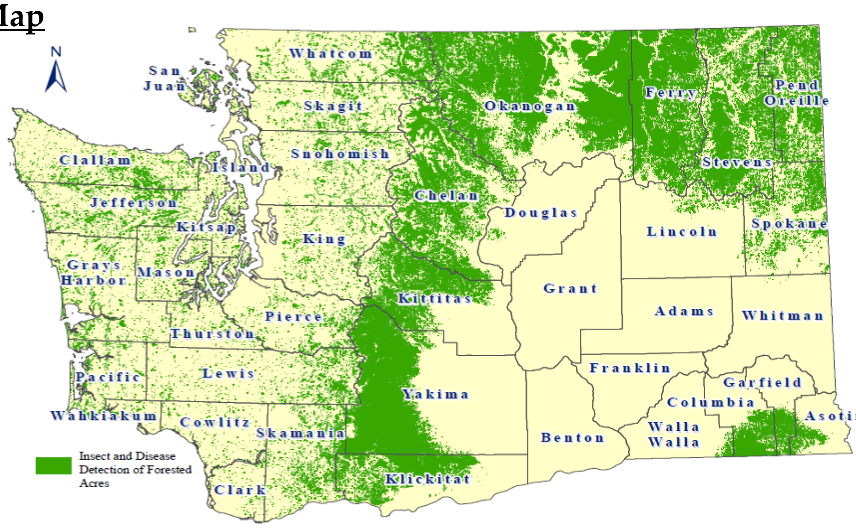


Figure 12-1 Insect and Disease Detection of Forested Acres in Washington, 1997-2007. Acres were detected via aerial surveillance flown over Washington's forested lands during the summer months of 1997 to 2007.

The hazard area map above (Figure 12-1) indicates acres of forested land detected to contain dead trees and foliage due to disease or insect infestations. The Washington State Department of Natural Resources and the U.S. Department of Agriculture – Forest Service Region 6, performed this survey. Areas not shown to contain disease or insect infestations may still contain them since this survey only looked at forested lands in Washington. Urban areas in the State may contain areas of infestations by non-native or native species of plants of animals, which would need to be determined by a local ground survey of the given area. Other areas not shown on the map as containing disease or insect infestations might also not fall into the category of forested area such as some eastern Washington counties, which contain a more desert landscape as opposed to dense forests.

Definitions

An infestation consists of an invasion or spreading of a living organism (plant, animal, etc.) that has an adverse (unwanted) effect on the population or the environment. The effect may range from a simple nuisance to an infectious disease or destructive parasite or insect. Infestations may result from non-indigenous plants, rodents, weeds, parasites, insects, and fungi, and may adversely affect people, animals, agriculture, economy (e.g., tourism), and property. Infestations generally refer to the occupation of a non-native species of plant or animal into a given area. Infestations can also include both native and non-native species that heavily colonized a particular habitat. These habitats can include city neighborhoods, forests, rivers, lakes, meadows, streams, grasslands, and other physical or natural environments all present in Washington.

History

Invasive species have been characterized as a "catastrophic wildfire in slow motion". Thousands of non-native invasive plants, insects, fish, mollusks, crustaceans, pathogens, mammals, birds, reptiles, and amphibians have infested hundreds of millions of acres of land and water across the United States, causing massive disruption in ecosystem function., reducing biodiversity, and degrading ecosystem health in forests, prairies, mountains, wetlands, rivers, and oceans. Invasive organisms affect the health of not only forests and rangelands but also of wildlife, livestock, fish, and humans.

A species is considered invasive if it meets these two criteria:

1. It is nonnative to the ecosystem under consideration, and
2. Its introduction causes or is likely to cause economic or environmental harm or harms to human health (this is according to *Presidential Executive Order 13112*).

One of the world's largest infestations is happening in British Columbia, Canada with the Mountain Pine Beetle (Figure 12-2). Normally a native insect in low populations in lodge pole pine forests of western North America, recent milder winters and a century or more of forest fire suppression have combined to create ideal infestation conditions for this species.

Figure 12-2 British Columbia forest affected by an infestation of Mountain Pine Beetle

The combination of Western forests being full of mature pine, and the beetle's mortality rate being low, has resulted in the largest infestation ever recorded in North America. This infestation is also spreading at an alarming rate; by 2005, it had extended to 8.7 million hectares (21.5 million acres) of British Columbia forests (Figure 12-3). As of 2006, some 450 million cubic meters of pine had been killed; this is equal to about 6 years worth of timber harvests at pre-infestation levels. Forecasters believe that by 2013, about 80% of the province's mature pine may be affected. The pine beetle's mark on the forest, including ecosystems, habitat, watersheds, and other species, is matched by its impact on forest products companies and the communities supported by this industry.

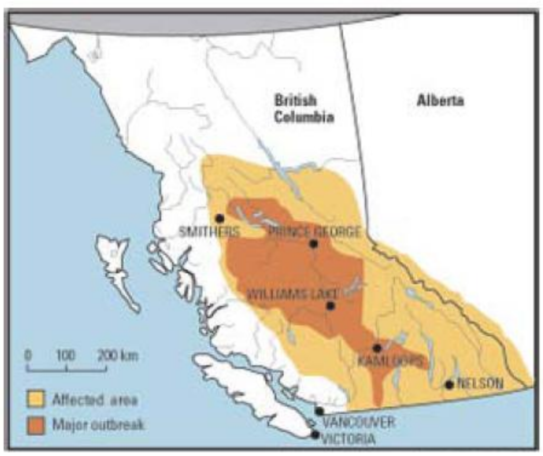


Figure 12-3 Affected areas of the Mountain Pike Beetle infestation in British Columbia, Canada

__Assessment__

Scientists propose several mechanisms to explain the infestations of invasive species, including species-based mechanisms and ecosystem-based mechanisms. Most likely, it is a combination of both of these mechanisms that cause an infestation of invasive species to occur since not all plants and animals become invasive. While all species compete to survive, invasive species have specific traits or combinations of traits that allow them to outcompete (for their needed elements of survival) against native species in the habitat in which they are introduced.

The U.S. Fish and Wildlife Service indentify 7 problems that invasive species and an infestation of such a species can cause:

- **A decrease in Biodiversity** – Invasive plants can dominate native plant communities by forming monocultures that use the resources (i.e. nutrients, light, and water) that native plants need to survive and grow.
- **Changes in Ecosystem Processes such as Fire, Nutrient Flow, and Flooding** – These changes have been experienced both in the Great Basin in Idaho and throughout Utah. Before the non-native European Cheat grass invaded this area fires occurred once every 60 to 110 years, now fires occur more frequent at a rate of every 3 to 5 years.
- **Hybridize with Native Plants and Cause Loss of Genetic Material** – Spreading populations of hybrid plants could result in the loss of genetic material and can lead to local extinction of the native species.
- **Agriculture and Livestock Effects** – Infestations of non-native species can outcompete with locally grown agriculture crops and overcome grasslands used by grazing livestock.
- **Hinder Efforts to Restore Threatened and Endangered Species** – About 42% of federally threatened and endangered species are at risk primarily because of invasive species.[72]
- **Reduce Recreational Opportunities** – The recreational activities normally enjoyed in rivers, stream, and lakes, such as swimming, boating, and fishing can all be impacted by an infestation of non-native aquatic plants. The health of the aquatic ecosystem can also decline in such as event.
- **Expensive to Control** – Invasive plant infestations can also reduce the economic benefits of recreation-based activities and the communities that support these activities. The environmental damage caused by invasive species, combined with the cost of controlling them, adds up to almost $120 billion dollars per year in the U.S.

Washington has several laws and administrative codes that govern infestations and invasive species. The Revised Code of Washington (RCW) 17.10.010 defines an invasive plant species (noxious weed) as a plant that, once established is highly destructive, competitive, and difficult to control using cultural or chemical (herbicide) practices. Other administrative measures define freedom from infestation for plants sold in Washington (Washington Administrative Code (WAC) 16.402.005), restricted shellfish areas where infection or infestation of shellfish is present (RCW 77.60.060), and the procedures for determining the danger of an infestation of plant pests or plant diseases (RCW 17.24.171).

Climate change is becoming an increasing concern and thus is necessary to address this topic in terms of its potential impact to infestations and its ability to increase the risk or vulnerability to these events. There are several factors that underlie how climate change impacts infestation of insects. The two dominant environmental factors are changes in temperature and moisture. Changing insect-host relationships and non-host species impacts, such as predation and disease, also play essential roles. Since insects are cold-blooded, they are extremely sensitive to temperature, being most active at warmer temperatures. As average winter temperatures rise as predicted due to global climate change, there will be fewer freezing conditions that normally keep insect populations at normal levels. Shorter winters, increasing summer temperatures, and fewer late-spring frosts correlate to increased insect feeding, faster growth rates, and rapid reproduction. All of these factors can easily lead to an insect infestation if interventions are not taken.[73]

For plant species, a changing climate may also increase the likelihood of infestations by non-native species. Because of the rapidity of expected changes in climate, individuals of a native plant species may be lost from their lower-elevation limits faster than they will be able to migrate upward and establish into newly created habitat. This will result in stressed communities with fewer plant species distributed over large areas of the landscape. Such ecosystems have an increase in the quantity of unused resources. These stressed communities thus become more open and their resources become more available for the infestation and establishment of invasive plant species.[74]

The factors that would determine which areas of Washington are more or less vulnerable to an infestation is difficult to determine without knowing what type of animal or plant that would be involved in such an event. One factor for infestations that seems to be present from the vast amounts of research done on this topic is that they typically start and occur in forested areas. This does not mean that urban areas and other types of ecosystems are not susceptible, but the abundant amount of habitat and nutrients in forests make these areas more ideal hosts for an infestation to occur. With this in mind, vulnerability to infestations is going to be higher in counties in Washington that contain large amounts of forested acres. While data containing all acres of forested land contained in Washington is not readily available, a good start to determining which counties contain forested land is to look at national forests, national parks, and national recreation areas within the State. The counties that include one or more of these areas include: Asotin, Chelan, Clallam, Columbia, Cowlitz, Ferry, Garfield, Grays Harbor, Island, Jefferson, King, Kittitas, Lewis, Lincoln, Mason, Okanogan, Pend Oreille, Pierce, San Juan, Skagit, Skamania, Snohomish, Stevens, Walla Walla, Whatcom, and Yakima counties (Figure 12-4). Other counties not included in this list may also contain forested acres of land, which should be determined at the local level as a means of identifying the occurrence of infestations.

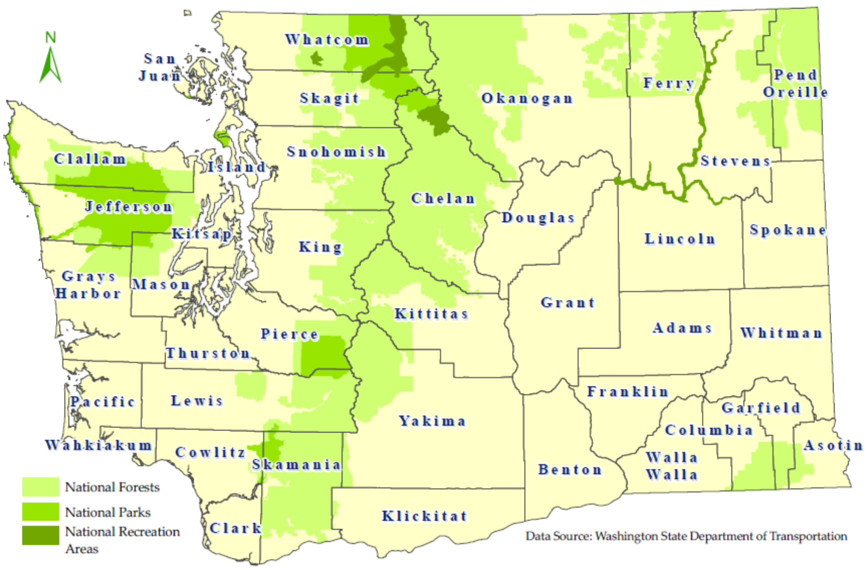


Figure 12-4 Locations of National Forest, Parks & Recreation Areas with Washington State

The potential for an infestation to occur is equally as difficult to determine without knowing ahead of time what plant or animal species is going to be part of the infestation. This is particularly difficult because plants and animals all require a unique blend of habitat and access to nutrients that makes pinpointing a particular area more at risk then others impossible without knowing which particular species in question. In order to prevent animal and plant species from becoming a problem, early detection, followed by a rapid response to eradicate initial infestations is necessary to maintain the health of Washington's unique ecosystems. This will be possible only if these infestations are located because of regular, detailed monitoring. Once an invasive plant or insect species has become established, a strategic approach for control and management then becomes a necessity.

A successful control or management effort for invasive species requires an active program of restoration or rehabilitation. Because each situation is unique, each site will require a program designed for its unique landscape characteristics to successfully accomplish the needed restoration or rehabilitation of the affected ecosystem.

Internet Resources

Washington Invasive Species Council
www.rco.wa.gov/invasive_species/default.htm

Washington Department of Fish and Wildlife- Aquatic Nuisance Species
http://wdfw.wa.gov/fish/ans/index.htm

Washington State Noxious Weed Control Board
www.nwcb.wa.gov/index.htm

Landslide

Frequency	Annually
People	
Economy	
Environment	
Property	$100-500M

Risk Level

- Frequency – Landslides happen in Washington on an annual basis.
- People – Though landslides can adversely affect or kill people, the likelihood that a landslide would kill enough people to meet the minimum threshold for this category is felt to be highly unlikely.
- Economy – While the cost of recovery from a landslide or the money it takes to prevent a landslide from persisting further down its intended path is substantial, the likelihood that a landslide would cost 1% of the State's Gross Domestic Product (GDP) to meet this category's minimum threshold is highly unlikely.
- Environment – While the environment and species that inhabit the areas in and around a landslide can be adversely affected in an event, the likelihood that 10% of a single species or habitat will be lost due to a landslide is highly unlikely.
- Property – During the week of February 4, 1996, sustained heavy rainfall at lower elevations caused more than $300 million dollars worth of damage due to flooding and land sliding in the Puget Sound region.

Hazard Area Map

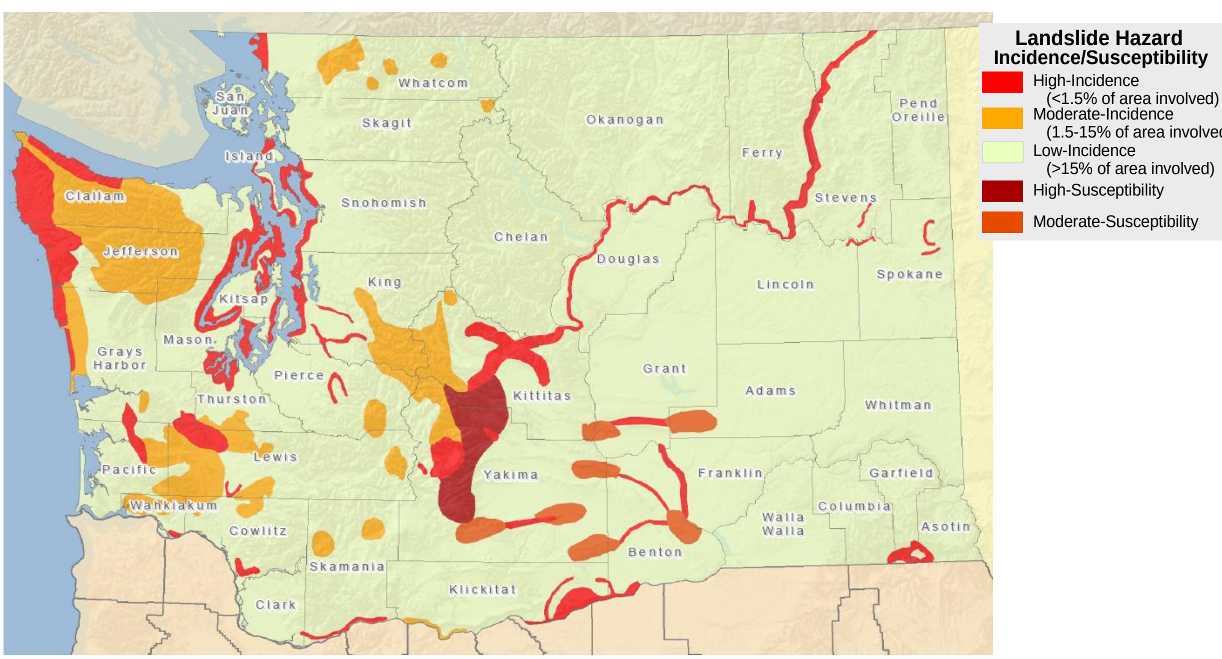


Figure 13-1 Landslide Hazards in Washington State

The landslide hazard map for Washington (Figure 13-1) was derived from the United States Geological Survey (USGS)[75] open-file report titled, Landslide Overview Map of the Conterminous United States. A GIS data file was obtained for this map from the USGS and the landslide hazards for Washington were extracted out to create the map. Landslide hazard areas are colored similar to the colors used for the original U.S. map. The landslide hazard is based on either the landslide incidence or the susceptibility of a landslide to occur in a given area. Susceptibility is not indicated on the map where it is the same or lower than incidence. "Susceptibility to land sliding was defined as the probable degree of response of [the areal] rocks and soils to natural or artificial cutting or loading of slopes, or to anomalous high precipitation. High, moderate and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding."

Definition

"The term landslide includes a wide range of ground movement, such as rock falls, deep failures of slopes, and shallow debris flows."[76] Although gravity acting on an over-steepened slope is the primary reason for a landslide, there are other factors:

- Creation of over steepened slopes due to erosion by ocean waves or rivers.
- Rock and soil on slopes weakened by saturation of heavy rainfall or snowmelt.
- Earthquakes generating weakened slopes.
- Volcanic eruptions that produce debris flows (such as the Mount St. Helens eruption of 1980), and or lahars.
- Man-made structures creating stress on weak slopes.
- Inadequate grading or drainage of a construction site.

Our focus on the landslide hazard for Washington will fixate on the definition of a landslide that concerns the "rapid downward sliding of a mass of earth and rock".[77] With this definition in mind, the Washington State Department of Ecology centers on three different types of landslides that are of concern in the Puget Sound and coastal regions of Washington.

The first is known as a deep-seated landslide (Figure 13-2). This type of slide "is often referred to as ancient landslides" and may have "existed for several millennia." These slides tend to activate "every few years to decades" in response to particularly wet conditions. "Typically, these large slides range in size from

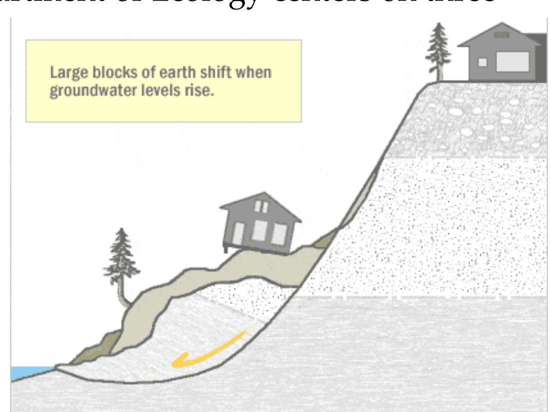


Figure 13-2 Deep-seated Landslide

less than an acre to several that extend over a mile of shoreline. The large ones often consist of several smaller blocks that may move independently."[78] Also known as rotational earth movements, these slides rotate the earth and rock backward as gravity pulls the mass of the slide downward. This type of landslide has been seen all over Washington, with a recent occurrence in 1999 at Carlyon Beach near the city of Olympia, which forced over thirty families from their homes.

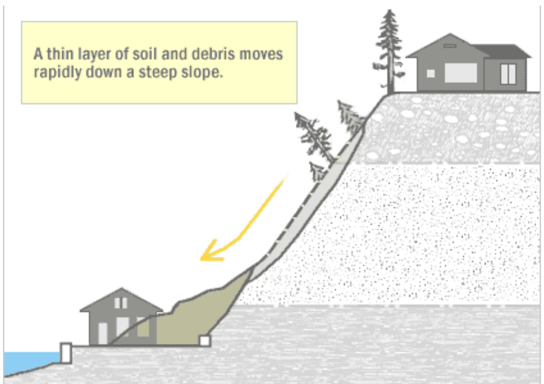


Figure 13-3 Shallow Landslide

The second type of landslide is a shallow slide (Figure 13-3). These slides "are frequent and widespread along Puget Sound's shoreline, typically occurring during prolonged periods of heavy rainfall. They involve a relatively thin layer (less than five feet) of wet soil and vegetation, but can be dangerous, as mud and debris travel fast and with destructive force". These slides "are usually small and rarely results in serious damage". The greatest danger from this type of slide is "to homes or structures built close to the toe of the slope, where they may be struck or buried by rapidly moving mud and debris".

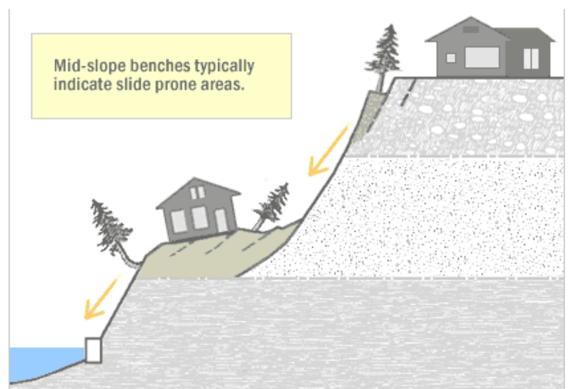


Figure 13-4 Bench Landslide

The third and final type of landslide is a bench slide (Figure 13-4). "Benches may occur along layers of resistant geologic materials, where long term erosion or land sliding of the overlying units has produced a stepped slope. Benches present an attractive site for development, since they offer level ground near the water on otherwise steep terrain. In many places, roads have been built down the steep upper slope to serve home sites along the bench itself." Examples of benches can be seen "along the shoreline north of Kingston, above the railroad grade north of Carkeek Park in Seattle and on Magnolia Bluff in Seattle".

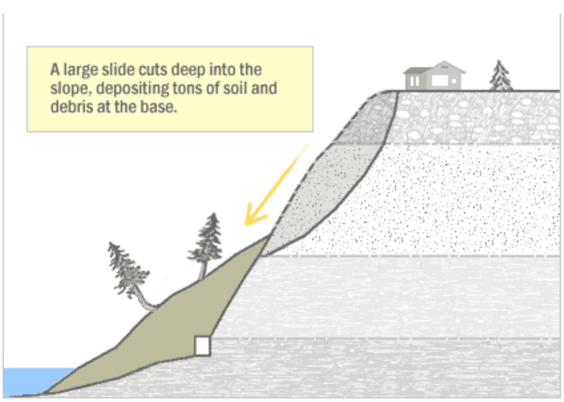


Figure 13-5 Large Scale Landslide

Although not considered one of the three types of landslides, large-scale landslides (Figure 13-5) periodically strike the Puget Sound's shoreline.

"These large slumps or slides can cut 50 or more feet into the upland and involve tens of thousands of tons of earth. Fortunately, such slides are relatively rare on Puget Sound, but the potential consequences along a developed shoreline would be catastrophic. Geologists understand little about these large landslides and therefore cannot easily predict when or where future slides might happen."

History

"Landslides in the United States cause approximately $3.5 billion (year 2001 dollars) in damage, and kill between 25 and 50 people annually. Rock falls, rockslides, and debris flow primarily cause casualties in the United States. Worldwide, landslides occur and cause thousands of casualties and billions in monetary losses annually."[79]

Washington is prone to landslides due to its unique geology, with over 660 miles of pristine waterfront and the geological makeup of its soil. Most landslides in Washington occur after intense periods of rainfall on already saturated soils. One of these events occurred in the winter of 1996 (February) in which an excess of 29 inches of rain fell in the Puget Sound lowlands over a period of 3 to 4 days resulting in widespread landslides and flooding causing more than $300 million dollars (1996 dollars) in damages. Large amounts of snow fell in the Puget Sound in December 1996, followed by rapid melting of snow from the large amounts of rain that followed. The rapidly melting snow and rain caused widespread flooding and landslide in January and mid-March 1997, as additional rain triggered more landslides.[80]

Figure 13-6 Rolling Bay, Bainbridge Island Landslide, 1997

One widely publicized landslide from the 1997 event resulted in the deaths of four family members when a shallow debris flow landslide on Bainbridge Island, completely consumed and destroyed their home (Figure 13-6). Another event, in Woodway resulted in the derailment of five cars of a Burlington-Northern-Santa Fe freight train.

The most costly landslide in United States history, at an estimate of $200 million dollars, (1984 dollars) occurred in Thistle, Utah (Figure 13-7). In the spring of 1983, unseasonably warm weather and rapid snowmelt resulted in a landslide that destroyed the railroad tracks of the Denver and Rio Grande Western Railway Company, and the adjacent Highway 89, flowing across the Spanish Fork River forming a dam. The impounded river water inundated the small town of Thistle, of which the entire town had to be evacuated as the lake began to flood the town. Within a day, the town was completely covered with water. Populations of people downstream from the dam were at risk because of the possible overtopping of the landslide by the lake, with a risk of outburst of the dam and massive flooding downstream. The Thistle landslide eventually reached a state of equilibrium across the valley but fears of reactivation caused the railway to construct a tunnel through bedrock around the slide area and the realignment of the nearby highway. In addition, the lake caused by the landslide was drained, with the resulting sediment partially burying the town of Thistle. None of the town's former inhabitants returned after this landslide.[81]

Figure 13-7 Thistle, UT Landslide – April 1983

Assessment

"Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past history of a site and by making inquiries to planning and engineering departments of local governments." In addition, it is highly advised to consult "the professional services of an engineering geologist, geotechnical engineer, or a civil engineer, who can properly evaluate a site, built or un-built".

With the advent of global warming coming into worldwide focus, it is only fitting to discuss its possible effects on landslide hazards. "Antoni Lewkowicz of the University of

Ottawa has studied several northern landslides and rockslides that he says can be at least partially attributed to thinning and weakening of ice or permafrost caused by climate change."[82] Other experts from the United Nations University say, "If climate change predictions are accurate you will expect … more intense and extreme rainfalls",[83] which could result in more landslides throughout the world.

The hazard associated with landslides "can be reduced by avoiding construction on steep slopes and existing landslides or by stabilizing the slopes". Slope stability will increase with one or more of the following actions: when ground water can be prevented from rising in the landslide mass by covering the landslide with an impermeable membrane, directing surface water away from the landslide area, draining the ground water away from the slide area, or minimizing surface irrigation. Slope stability can also increase when a "retaining structure and/or the weight of a soil/rock berm are placed at the toe (bottom) of the landslide or when mass is removed from the top of the slope". City, county, and state mitigation plans can be a further source of information for strategies to reduce the impacts and potential for landslides and their associated hazards in Washington.

"Although the physical cause of many landslides cannot be removed, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can (greatly) reduce landslide hazards".

Internet Resources

United States Geological Survey, Landslide Hazards Program
http://landslides.usgs.gov/

Washington State Department of Natural Resources, Landslide Hazard Zonation Project
http://www.dnr.wa.gov/BusinessPermits/Topics/LandslideHazardZonation/Pages/fp_lhz_review.aspx

United States Geological Survey, Landslide Hazards, USGS Fact Sheet 071-00
http://pubs.usgs.gov/fs/fs-0071-00/

United States Geological Survey, Landslide Overview Map of the Conterminous United States
http://landslides.usgs.gov/learning/nationalmap/

Pipelines

Frequency	1-10 yrs
People	
Economy	1-2% GDP
Environment	
Property	$100-500M

Risk Level

- Frequency – History of pipeline incidents indicates that a pipeline incident occurs in Washington approximately every 1 to 10 years.
- People – Although people have been injured and killed by a pipeline incident, past incidents have not reached the minimum threshold for this category.
- Economy- A pipeline incident can affect the major transportation routes throughout the State and could cause major disruption to movement of goods by truck, rail, and air; resulting in a major hit to the State’s economy.
- Environment – Although the environment and the species that inhabit these areas can be affected by a pipeline incident due to a spill of hazardous materials, it is not felt that such an incident will eradicate 10% of a single species or habitat.
- Property – Based on past property damage of other states as a result of a pipeline incident, an incident occurring in a heavily populated area of the State could generate property damage in the range of $100-500 million dollars.

Hazard Area Map

Figure 14-1 Washington State Pipeline Distribution Network. The location of pipelines responsible for carrying natural gas, petroleum products (including jet fuel, gasoline, etc.), and crude oil located with Washington State.

The hazard map (Figure 14-1) indicates the location of natural gas, petroleum products, and crude oil pipelines in Washington. As shown in the map, the pipelines mainly traverse through the counties in Washington situated along the Interstate 5 corridor, in counties located along the southern Washington/Oregon border, and in the counties located in the eastern and southeastern portions of the State.

Definition

A pipeline is defined as a transportation artery that is capable of carrying liquid and gaseous fuels. Pipelines can be buried beneath the surface or can be placed above ground.

Washington State has the following types of pipelines: crude oil, petroleum products, and natural gas. These types of fuels are defined as:

- **Natural Gas** – Underground deposits of gases consisting of 50 to 90 percent methane (CH_4) and small amounts of heavier gaseous hydrocarbon compounds such as propane (C_3H_8) and butane (C_4H_{10}).[84]
- **Crude Oil** – The term used to define petroleum as it comes directly out of the ground. It is a varied substance, both in its use and composition. It can be a straw colored-liquid or a tar-black or semi-solid. Red, green, and brown hues of crude oil are common.[85]
- **Petroleum Products** – Petroleum products is a generic name for hydrocarbons, including crude oil, liquid natural gas, natural gas, and their products. Petroleum products include; gasoline, kerosene, jet fuel, heavy fuel oil, petroleum jelly, and paraffin.[86]

History

The Washington State Utilities and Transportation Commission (UTC) is the responsible agency for the inspection and regulation of pipelines in Washington. The Commission's pipeline safety program began inspecting natural gas systems operating in Washington in 1955. Intrastate hazardous liquid pipelines were added to the Commission's responsibilities in 1996. In 2000, the Washington State Legislature approved the *Pipeline Safety Act* (HB2420), which directed the Commission's pipeline safety program to seek federal approval to include inspections of all interstate pipelines. In 2001, the State Legislature adopted the *Pipeline Safety Funding Bill* (SB 5182). In addition, in 2003, the Washington UTC became the lead inspector for all interstate pipeline inspections and incidents. The State Pipeline Inspection Program is supported through a combination of federal grants and pipeline fees.

Three notable pipeline incidents occurred in Washington in the past 10 years. On February 8, 1997, a natural gas pipeline caught fire and exploded near Everson. The explosion occurred in a remote area of mostly wooded and mountainous terrain, which was a former glacier slide area. The 26-inch pipeline involved in the explosion failed due to ground movement of water-saturated soil. The following day, February 9, 1997, a natural gas pipeline caught fire and exploded near Kalama. This explosion also occurred in a remote area and was the result of ground movement that caused a break at a weld within the pipeline resulting in the explosion. Lastly, a gasoline pipeline leak caught fire and exploded at Whatcom Fall Park in the city of Bellingham on June 10, 1999. The ruptured line leaked 277,000 gallons of gasoline into a creek bed and resulted in three casualties.

Events such as flooding and earthquakes can increase the likelihood of a pipeline incident. The Northridge Earthquake occurred on January 17, 1994 and damaged buildings, highways, and other structures in Southern California. In addition to building and highway damage, this earthquake damaged several crude oil underground pipelines in the area. One of these pipelines ruptured and spilled 177,000 gallons of crude oil into a storm drainage system, which flowed into the Santa Clara River. The crude oil flowed down the river for about 16 miles causing extensive environmental damage.

Figure 14-2 San Jacinto River Flooding and Pipeline Explosion, October 19-20, 1994

Heavy rains and catastrophic flooding of the San Jacinto River near Houston, Texas caused eight oil pipelines to rupture and burn on October 19-20, 1994 (Figure 14-2). The surging floodwaters of the river washed away soil over and under the pipelines involved in the incident, exposing them to intense hydraulic pressures that bent and twisted them until they eventually burst. These pipeline ruptures, spilled an estimated 2.5 million gallons of crude oil, refined petroleum products, and liquefied petroleum gas into the river and Galveston Bay. The fires resulting from this incident caused extensive damage to many structures that were thus unaffected by the flooding and injured an estimated 1,830 people.

Although only affecting the immediate area in which these incidents occur, these spills illustrate the vulnerability of pipelines in earthquake-prone and flood prone areas. Pipeline vulnerabilities to both earthquakes and flooding should be considered when designing and building new pipelines due to the history of these events in Washington.

Assessment

There are 28 pipeline companies in Washington with the responsibility for the operation of 24,000 miles of pipelines. Over 22,000 miles of pipeline provide natural gas to residential neighborhoods and over 700 miles of pipelines carry gasoline, diesel, jet fuel, crude oil, and butane. Twenty of the 28 pipelines carry natural or hydrogen gas and 8 of these carry hazardous liquids such as crude oil, gasoline, and jet fuel. There are 8 interstate pipelines in Washington – 5 carry liquids and 3 carry natural gas. Interstate pipelines typically are large diameter pipelines that operate at very high pressures.

The transportation of hazardous liquids and gases is safer by pipelines then by any other means (Figure 14-3). However, if an incident occurs at a pipeline the results could be disastrous. Pipelines in Washington were all originally located in areas away from major cities and populated centers. However, with the continued expansion of the population in the State, especially the Puget Sound region, many people now live closer to pipelines then were originally planned. Many of these pipelines are within a few blocks of schools and in one case in Pierce County, actually run under a school playground. A major break in a pipeline at one of these locations could not only shut down major transportation routes for a short period of time to deal with the response but could affect a large portion of the community in which the event occurs.

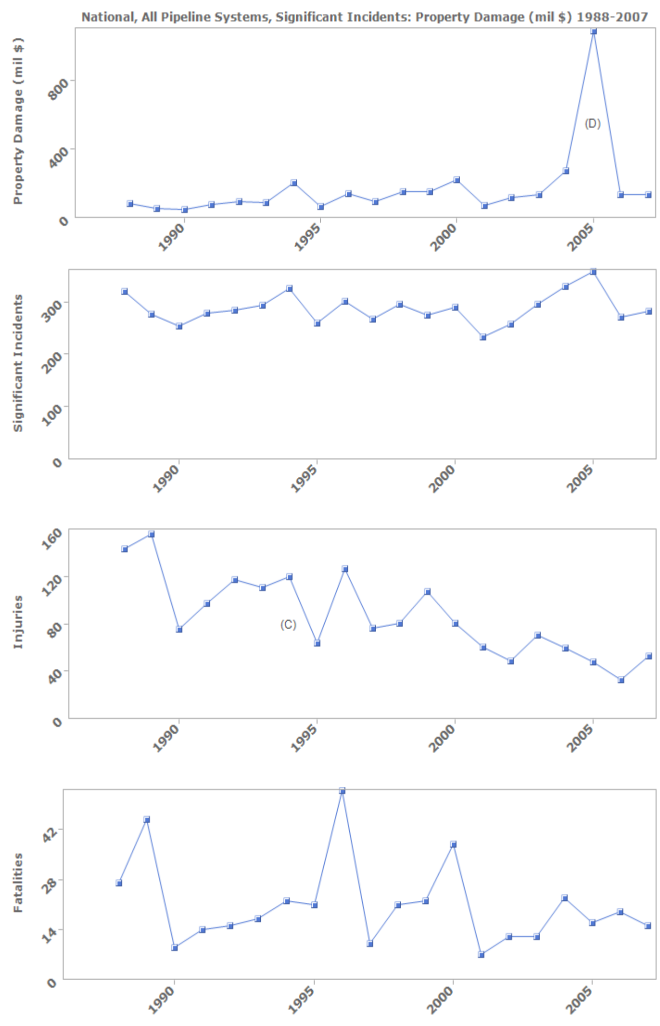


Figure 14-3 U.S. Pipeline Significant Incidents from 1988-2007

Pipeline incidents are the results of a rupture or break in a pipeline that causes a fire or explosion. The rupture or break can cause fires in urban and forested areas resulting in property damage to residential and commercial property. Environmental damage can also be caused by a pipeline incident in the form of a wildfire or the release of the hazardous product contained in the damaged pipeline into streams, rivers, or other sensitive habitat.

Populations that exist near pipelines are all potentially vulnerable to an incident. Those pipelines that are near rivers or streams with a history of flooding are also potentially vulnerable to a rupture should a flooding incident occur at one of these locations. Pipelines on or near earthquake faults that exist in Washington are also potentially vulnerable to a rupture or break if an earthquake should occur.

The best way to reduce the number of pipeline incidents occurring in Washington is to have pipeline companies fully comply with the safety measures set forth in the Pipeline Safety Act and for the Washington Utilities and Transportation Commission (UTC) to make regular inspections of pipelines. After an earthquake or flood incident the UTC should provide an immediate inspection of each pipeline in the affected area and alert the proper pipeline company if damage is found.

Possible broad mitigation strategies for reducing the vulnerability and risks associated with pipelines include: enhancing public education and awareness on the hazards of pipelines and their location near communities and populated centers; improving communication and information sharing between pipeline companies and local government agencies, particularly those involved with land-use planning and emergency management and response; and enhancing pipeline company support and cooperation with local emergency first responders.

Internet Resources

National Pipeline Mapping System, Pipeline and Hazardous Materials Safety Administration
www.npms.phmsa.dot.gov/

Pipeline companies Operating Pipelines in Washington, Washington Utilities and Transportation Commission
www.wutc.wa.gov/webdocs.nsf/vw2005/683735fdab201f8a88256c9f007ee4b2

Pipeline Company Inspection Reports, Washington Utilities and Transportation Commission
www.wutc.wa.gov/webimage.nsf/003e7e1f64b79b36882564b30062ac85/039ae615808059de882572b4005a6a09!OpenDocument

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Severe Storm

Frequency	Annually
People	
Economy	
Environment	
Property	$100-500M

Risk Level

- Frequency – Severe storms, which include any or a combination of: thunderstorms, hail, wind storms, lightning, or a tornado, happen annually in Washington.
- People – Looking at past history of injuries and deaths due to severe storms in Washington, the minimum threshold for this category is not met.
- Economy – According to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center, Washington has not experienced a severe weather event that totaled losses that met or exceeded the minimum dollar amount for this category.[87]
- Environment – Severe storms do affect the environmental landscape of Washington, but their effect does not meet the minimum threshold for this category.
- Property – Severe storms can have a large impact on the property of the state, both residential and commercial. The December 2006 windstorm affected all 39 counties and the estimate for damage is still being tallied and is greater than $50 million. Total property damage from the greatest windstorm to hit Washington is estimated at $235 million (1962 dollars). This was the Columbus Day Storm of October 1962, which was the strongest non-tropical storm to every hit the contiguous 48 states.

Hazard Area Map

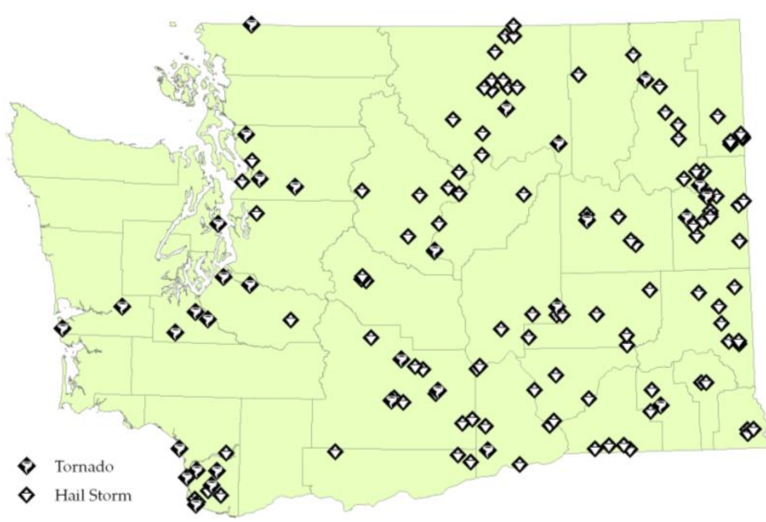

Figure 15-1 Severe Storm elements in Washington, 1997-2007. The severe storm elements of tornados and hail were collected from a Nation Weather Service data site and displayed for the years of 1997 through 2007. Tornados for these years were in the value of F-0 and F-1 or EF-0 to EF-1 if recorded after Jan. 2007. Hail for these years ranged in diameter from ½ to 2 inches.

Definition

A severe storm is defined as an atmospheric disturbance that results in one or more of the following phenomena: high winds, heavy snow, large hail, thunderstorms, lightning, tornados, rain, snow or other mixed precipitation. These elements are defined as follows, using the National Weather Service definitions:

- **High Winds** – Sustained wind speeds of 40 mph or greater lasting for 1 hour or longer, or winds of 58 mph or greater for any duration.
- **Severe Thunderstorm** – A thunderstorm that produces a tornado, winds of at least 58 mph (50 knots), and/or hail at least 1inche in diameter. A thunderstorm with wind equal to or greater than 40 mph (35 knots) and/or hail at least ½ inches in diameter is defined as approaching severe.
- **Tornado** – A violently rotating column of air, usually pendant to a cumulonimbus (type of cloud), with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud rotating noise. On a local scale, it is the most destructive of all atmospheric phenomena.
- **Heavy Snow** – This generally means: a snowfall accumulating to 4" or more in depth in 12 hours or less or a snowfall accumulating to 6" or more in depth in 24 hours or less
- **Lightning** – A visible electrical discharge produced by a thunderstorm. The discharge may occur within or between clouds, between the cloud and air, between a cloud and the ground or between the ground and a cloud.
- **Hail** – Showery precipitation in the form of irregular pellets or balls of ice more than 5 mm in diameter, falling from a cumulonimbus cloud.

History

Washington has had several notable severe storm events in its history including severe snowstorms, tornados and windstorms. The most notable snowstorm in Washington to date occurred during January and February of 1916. On February 1, 1916, Seattle recorded a record snowfall accumulation of 21.5 inches in a 24-hour period. Other parts of Washington received around 2 to 4 feet of snow that winter.

Although far from the famous "tornado alley", Washington has also experienced several severe storm events involving tornados. Washington's deadliest tornado outbreak occurred on April 5, 1972. On this day, an F-3 tornado (sustained winds of 158-206 mph) touched down in Vancouver causing 6 deaths, 300 injuries and an estimated $50 million in damage. Later that same day, another F-3 tornado touched down west of Spokane and an F-2 tornado (sustained winds of 113-157 mph) struck rural Stevens County. The state experienced another outbreak of tornados on May 31, 1997. On this day, a record six tornados touched down in Washington; four F-1 tornados (sustained winds of 73-112 mph) struck in Stevens and Spokane Counties and an additional two F-0 tornados (sustained winds of 40-72 mph) touched down, one in Vancouver and one in Tacoma. This severe storm also produced large hail up to 3 inches in diameter with heavy rain and wind gusts up to 80 mph.

Windstorms are experienced more often than tornados in Washington and cause millions of dollars in damage with each occurrence. The Columbus Day Windstorm that hit the Northwest on October 12, 1962 is the greatest windstorm to strike this area and has become the windstorm of which all others are compared. This storm was the strongest widespread non-tropical windstorm to hit the continental U.S. during the 20th century, with its effects felt from northern California to areas of British Columbia. The storm claimed 46 lives and caused the loss of power to over 1 million homes. More than 50,000 homes were damaged costing an estimated $235 million (1962 dollars).

Figure 15-2 Affects of December 2006 Windstorm. One of the may damaged homes resulting from falling trees due to strong winds from the storm.

Two more severe windstorms since the Columbus Day storm have both resulted in federal disaster declarations. The Inauguration Day Windstorm on January 20, 1993 (Federal Disaster #981) brought hurricane force winds (sustained winds or gusts of 74 mph or greater) to King, Mason, Lewis, Thurston, Snohomish, Pierce, and Wahkiakum Counties. This storm claimed 5 lives and resulted in the destruction of 52 homes and damaged an additional 249 homes and 580 businesses. Total damage resulting from this storm is estimated at $130 million. The most powerful windstorm since the 1993 storm occurred in December of 2006 (Federal Disaster #1682) (Figure 15-2). This storm brought 90 mile per hour winds to Washington's coastline and wind gusts of up to 70 mph in the Puget Sound region. The storm also knocked out power to 1.5 million Washington residents with some not seeing electricity restored for 11 days. A federal disaster declaration was declared for all 39 of Washington's counties and estimated damages exceeded $50 million dollars.

Assessment

According to the National Weather Service, severe storm events have produced some of the most significant weather events in Washington. These significant events include the Columbus Day Windstorm of 1962, the snowstorms in January of 1916 and 1950, the Inauguration Day Windstorm of 1993, the December 2006 Hanukkah Eve Windstorm, and most recently the December 2007 Winter Storm and Flooding.[88]

With weather patterns drawing much of their dependence and rate of occurrences on the climate of a given area, it is only fitting to address the impacts that global climate change may have to severe weather incidents. According to climate models done by the University of Washington's Climate Impacts Group, the rate of temperature change will increase in the Pacific Northwest as will the amount of temperature change. Seasons on average will all be warmer than previously experienced and the average annual temperature will likely exceed the range of the 20th century variability in the next 30 years in the Pacific Northwest. Precipitation in the Pacific Northwest is expected to increase by 1 to 2%, with more than half of the climate models projecting this increase in the winter (December-February) months and a large percentage of this precipitation will fall as rain rather than snow due to warmer winter temperatures.[89]

Changes in the behavior of climate patterns such as El Niño and La Niña that effect storms in Washington are not well modeled. Thus, there is insufficient information in order to make a prediction as to how climate change will affect these sources of inter-annual climate variability in the Pacific Northwest. While severe storms have impacted every corner and jurisdiction in the State, counties at most risk of a future severe storm event include those counties along the Pacific Ocean, counties located within the Puget Sound basin, counties along the eastern slopes of the Cascade Mountains, and the southeastern counties of Benton, Walla Walla, and Columbia counties, as well as Spokane County.

Because of Washington's location on the windward coast of the Northern Pacific Ocean, along with its mountainous topography, which influences precipitation patterns, Washington is assured of powerful severe storm events in the future. With the risk of severe storms impacting many Washington counties with significant populations, personal preparedness along with city and local preparedness planning for severe storm events may be able lessen the impact to individuals and local jurisdictions when the next severe storm occurs.

Internet Resources

National Oceanic and Atmospheric Administration, National Weather Service, Weather Glossary
www.weather.gov/glossary/

Current Weather Watches, Warnings and Advisories for Washington Issued by the National Weather Service
www.weather.gov/alerts-beta/wa.php?x=1

Washington State Emergency Management – Guide to Weather Safety
www.emd.wa.gov/publications/pubed/severe_weather_brochure.pdf

NOAA Weather Radio All Hazards
www.nws.noaa.gov/nwr/

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Terrorism

(Inc. Cyberterrorism & Weapons of Mass Destruction)

Frequency	1-10 yrs
People	10,000 – 50,000
Economy	1-2% GDP
Environment	
Property	$1B+

Risk Level

- Frequency – Due to the differing types of terrorism and the variety of terrorist, political, and social extremist groups that perpetuate these acts, the likelihood of any act of terrorism taking place in Washington is believed to be on the frequency of 1 to 10 years.
- People – If a terrorist attack were to occur in a highly populated city in Washington, it can be expected that 10,000 to 50,000 people could potentially be affected.
- Economy – Recent terrorist attacks in the United States severely affected the local economy of the cities in which they occurred. If a terrorist attack were to occur in Washington, a similar type of economic effect would be an expected result.
- Environment – Although the environment can be affected by an act of terrorism, the potential eradication of 10% of a habitat or a single species is considered to be unlikely.
- Property – If a 9/11-type, attack was to occur in a highly populated city it can be expected that damage would be in excess of $1 billion.

Hazard Area Map

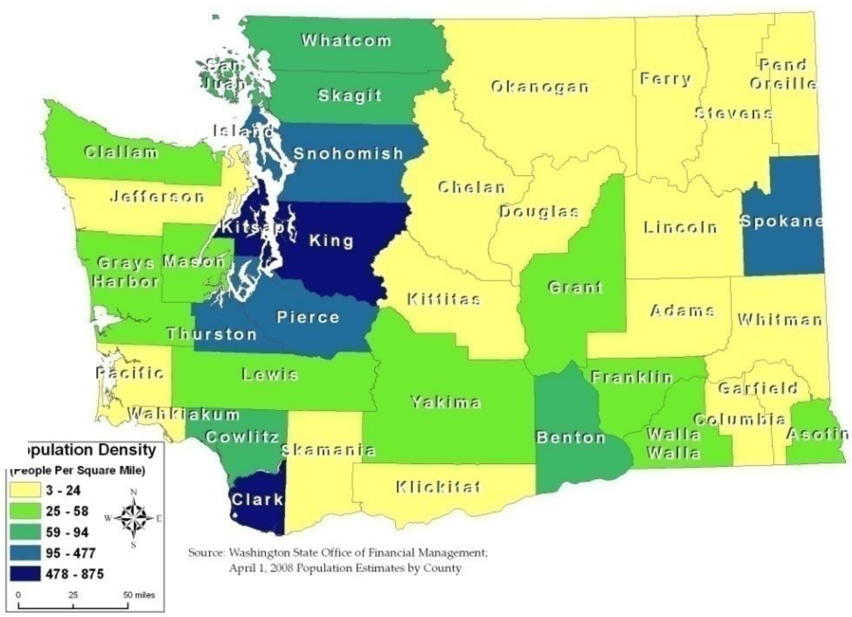


Figure 16-1 Population Densities of Washington State Counties. Population densities were based on April 1, 2008 estimates of county populations taken from the Washington State Office of Financial Management. Densities for each county are in people per square mile.

Potential terrorist targets are difficult to determine on an international scale let alone Washington. A common factor among terrorism organizations is their desire to commit acts of terrorism in highly populated or high profiles areas. We have seen evidence of this in the United States in New York City and Washington, D.C. and internationally with terrorism acts occurring in London, England and Madrid, Spain. The hazard map (Figure 16-1) displays the population densities of counties within Washington. Highly populated counties tend to have a heavier infrastructure base to support a large population and thus have more potential targets for a terrorism group seeking to inflict harm on these types of systems.

Definition

The Federal Bureau of Investigation (FBI) defines terrorism as "the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objective". The FBI further defines terrorism as either domestic or international, based upon the origin, base, and objectives of the terrorist organization.

"Domestic terrorism involves groups or individuals who are based and operate entirely within the United States and Puerto Rico without foreign direction and whose acts are directed at elements of the United States Government or [its] population."[90]

"International terrorism is the unlawful use of force or violence committed by a group or individual, who has some connection to a foreign power or whose activities transcend national boundaries, against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives."

"Cyberterrorism is the convergence of cyberspace and terrorism. It refers to [the] unlawful attacks and threats of attack against computers, networks, and the information stored therein when done to intimidate or coerce a government or its people in furtherance of political or social objectives." To qualify as Cyberterrorism, "an attack should result in violence against persons or property, or at least cause enough harm to generate fear". Attacks that lead to death or bodily injury, explosions, or severe economic loss are all examples of cyberterrorist related activities. Attacks against elements of a government's critical infrastructure could also be classified as acts of Cyberterrorism depending on the impact of such an event.[91]

A weapon of mass destruction (WMD) is defined by the FBI as "any explosive or incendiary device, as defined in *Title 18 USC, Section 921*, as a bomb, grenade rocket, missile, mine, or other device with a charge of more than four ounces. A WMD is further defined by this organization as “any weapon designed or intended to cause death or serious bodily injury through the release, dissemination, or impact of toxic or poisonous chemicals or their precursors. In addition, a WMD can be classified as “any weapon involving a disease organism or any weapon designed to release radiation or radioactivity at a level dangerous to human life”.[92]

History

The most recent occurrence of potential international terrorism to surface in Washington occurred in December of 1999 when a 32-year old Algerian man named Ahmed Ressam was arrested by U.S. Customs agents while trying to enter the United States from Victoria, British Columbia via a ferry to Port Angeles. Ressam was trying to enter the United States with 240 pounds of homemade explosives in the truck of his rented vehicle. He was charged with smuggling explosive material into the United States. Because the unlikelihood of the explosive materials being successfully smuggled onto the commercial aircraft the suspect was expected to depart on the following day, law-enforcement officials investigated the possibility of a terrorist bombing during the year 2000 New Year’s Eve celebration at Seattle’s Space Needle, since an event of this kind normally draws thousands of people in celebration. Later it was determined that the explosives were meant for a bombing at the Los Angeles International Airport that was to happen on New Year’s Eve.[93]

Although lately terrorism has been viewed as an external problem, homegrown or domestic terrorism events have also occurred in the U.S. in recent years. These events include the bombing of the Alfred P. Murrah Federal Building in Oklahoma City in April of 1995, the DC Sniper Shootings in October of 2002, and an incident involving the University of Washington’s Center for Urban Horticulture Building (Figure 16-2) which was set ablaze by members of the environmental extremist group Earth Liberation Front (ELF) in May of 2001.[94]

Figure 16-2 University of Washington Center for Urban Horticulture, 2001. This is all that remained of the UW building after being destroyed by arsonists from the group Earth Liberation Front (ELF).

Assessment

The FBI is the leading agency in the United States for all matters concerning terrorism. The Seattle office of the FBI has three tasks forces operating to address terrorism matters, these are:

- The Puget Sound Joint Terrorism Task Force (PSJTTF)
- The Puget Sound Counterterrorism Working Group (PSCTWG)
- The Inland Northwest Regional Terrorism Task Force (INRTTF)

These FBI task forces work in conjunction with local and state law enforcement agencies to share information and to conduct terrorism investigations. For matters relating to cyberterrorism, the FBI has created a Northwest Cyber Crime Task Force (NWCCTF). This task force is comprised of investigators from the FBI, U.S. Secret Service, Internal Revenue Service, Washington State Patrol, and the Seattle Police Department. The NWCCTF has four main investigative priorities: computer intrusions, intellectual property crimes, child pornography crimes, and internet fraud.

Communities vulnerable to terrorist incidents are those that have high visibility or are internationally known and those communities containing highly visible targets. These critical facilities, sites, systems, and or special events are usually located near high-volume transportation routes with multiple access points. These facilities include:

- Government office buildings, courthouses, schools, hospitals, and shopping malls
- Dams, water reservoirs, and the power distribution network
- Military base
- Railroads, interstate highways, tunnels, airports, ferries, bridges, seaports, and hazardous materials pipelines
- Sport stadiums, concert venues, convention centers, theatres, parks, and casinos
- Financial institutions and banks
- Historical landmarks and monuments
- Scientific research facilities, museums, and institutes of higher learning
- Special events, parades, religious services, festivals, and celebrations

These critical facilities, sites, and special events become even more appealing as potential terrorist targets during visits by high profile personalities and dignitaries.

A concern among law enforcement agencies is the potential for terrorists to utilize a WMD to carry out an act of terrorism. The Council on Foreign Relations (CFR) debated this question recently concerning the likelihood of a nuclear terrorist attack in the United

States. Graham T. Allison, the Director of Harvard's Belfer Center for Science and International Affairs, replied to this question by citing several references of estimates of a nuclear attack on U.S. soil to be between 50% in the next decade to a 20% yearly probability within a European or American city, to a 29% probability over a ten-year period.[95] "Prior to 9/11, most terrorism experts argued that terrorists sought not mass casualties but rather mass sympathy through limited attacks that called attention to their cause." After the 9/11 attacks, "the 9/11 Commission issued its major conclusion: The principle failure to act to prevent the September 11 attack was a 'failure of imagination'." According to Mr. Allison, "a similar failure of imagination leads many today to discount the risk of a nuclear 9/11". Whatever the risk of nuclear terrorism may be, "even a small chance of catastrophe is worth being concerned about" according to CFR Fellow Michael Levi.

Cyberterrorism is an attractive option of modern terrorists for several reasons. "First, it is cheaper than traditional terrorist methods. All that the terrorist needs is a personal computer and an online connection. Terrorists do not need to buy weapons such as guns and explosives; instead, they can create and deliver computer viruses through a telephone line, a cable, or wireless connection. Second, cyberterrorism is more anonymous than traditional terrorist methods. Like many internet surfers, terrorists use online nicknames – "screen names" – or log on to a website as an unidentified "guest user", making it very hard for security agencies and police forces to track down the terrorists' real identity. And in cyberspace there are no physical barriers such as checkpoints to navigate, no borders to cross, and no custom agents to outsmart. Third, the variety and number of targets are enormous. The cyberterrorist could target the computers and computer networks of governments, individuals, public utilities, private airliners, etc.

The sheer number and complexity of potential targets guarantee that terrorists can find weaknesses and vulnerabilities to exploit. Several studies have shown that critical infrastructures, such as electric power grids and emergency services are vulnerable to a cyberterrorist attack because the infrastructures and the computer systems that run them are highly complex, making it effectively impossible to eliminate all weaknesses. Fourth, cyberterrorism can be conducted remotely, a feature that is especially appealing to terrorists. Cyberterrorism requires less physical training, psychological investment, risk or mortality, and travel than conventional forms of terrorism, making it easier for terrorist organizations to recruit and retain followers."[96] Finally, the 2000 I LOVE YOU virus "showed, cyberterrorism has the potential to affect directly a larger number of people than traditional terrorist methods, thereby generating greater media coverage, which is ultimately what terrorists want".

January 2008 marked the passing of Homeland Security Presidential Directive 23, which established the Comprehensive National Cyber Initiative (CNCI).[97] Since then and for the first time in history, the Department of Homeland Security, along with the Department of Defense, FBI, and intelligence community have an integrated strategy and action plan to improve cyber security across federal, military, and civilian networks. Other security measures have taken place prior to and since the events of September 11, to make it more difficult for an act of terrorism to again take place on American soil. Even with all these controls, the risk and vulnerability to terrorism can never be completely eliminated. Although the fear of terrorism or cyberterrorism may be over-exaggerated and manipulated at times, it would be foolish to deny or ignore its possibility. "Paradoxically, success in the "war on terror" is likely to make terrorists turn increasingly to unconventional weapons, such as cyberterrorism. And as a new, more computer-savvy generation of terrorists comes of age; the danger seems set to increase". In turn, it is necessary to continue to create plans, investigate potential threats and put in place roadblocks to prevent current and emerging threats of terrorism both locally and nationally to protect the people, the economy, and property of Washington.

Internet Resources

Federal Bureau of Investigations, Seattle Division
http://seattle.fbi.gov/

U.S. Department of Homeland Security
www.dhs.gov/index.shtm

Washington State Patrol, Homeland Security Division
www.wsp.wa.gov/crime/homeland.htm

Tsunami

Frequency	50+ yrs
People	50,000
Economy	1% GDP
Environment	
Property	$100-500M

Risk Level

- Frequency – Based on geologic evidence along the coast of Washington, the Cascadia Subduction Zone (CSZ) has ruptured and created tsunamis at least 7 times in the past 3,500 years and has a considerable range in recurrence intervals, from as little as 140 years between events to more than 1,000 years. The last CSZ-related earthquake is believed to have occurred in 1700 and researchers predict a 10 to 14 % chance that another could occur in the next 50 years.[98]
- People – According to a recently released study by the U.S. Geological Survey, the tsunami inundation zone along the coast of Washington contains more than 42,000 residents that could potentially be affected were a tsunami to occur.
- Economy – The tsunami-inundation zone contains 2,908 businesses representing 31% of the businesses located in the four coastal counties of Washington most prone to the effects of a Cascadia Subduction Zone generated tsunami[100]. If a tsunami were to occur, the economic impact to these four counties could be severe and the State's economy would also be impacted.
- Environment – The potential impact to the environment due to a tsunami does not meet the minimum threshold for this category.[99]
- Property – A USGS study on the vulnerability of Washington communities found that 18,397 households are in the tsunami-inundation zone along the coast of Washington.[100] Property damage to these homes could be between $100 and $500 million dollars depending on the severity of the tsunami.

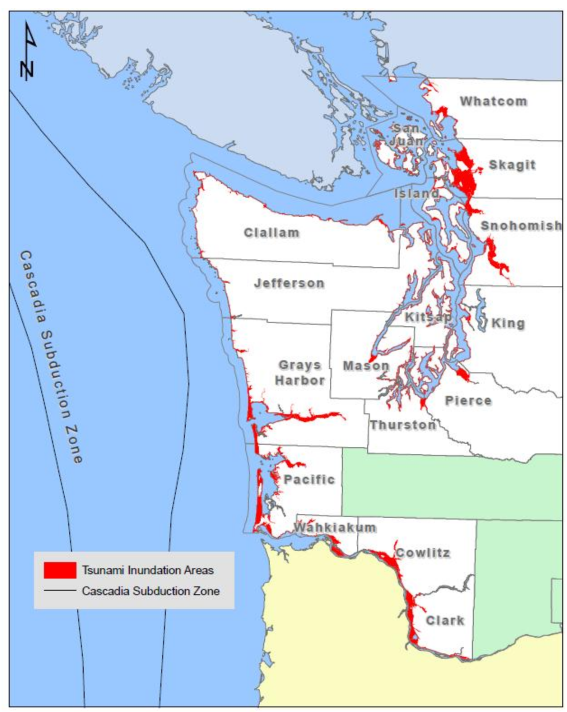


Figure 17-1 Tsunami Inundation Map for Washington State

Hazard Area Map

The tsunami inundation areas indicated on the map (Figure 17-1) were derived from 25-foot contour lines. This height of 25 feet was determined to be a plausible wave height for a coastal or Puget Sound located tsunami to be able to reach and cause flooding and other types of damage.[100] While tsunamis can occur in the Puget Sound, it is thought only a to be possibility if an earthquake is centered in this region and results in a tsunami. A coastal tsunami is not thought to be able to reach the Puget Sound area as the waves have many obstacles prior to reaching this region. The Cascadia Subduction Zone is a region "where an oceanic tectonic plate (the Juan de Fuca plate) is being pulled and driven (i.e. subducted) beneath a continental plate (the North American plate). Earthquakes along the fault that is the contact between the two plates, termed the interpolate thrust or megathrust, may generate significant local tsunamis in the Pacific Northwest".[101]

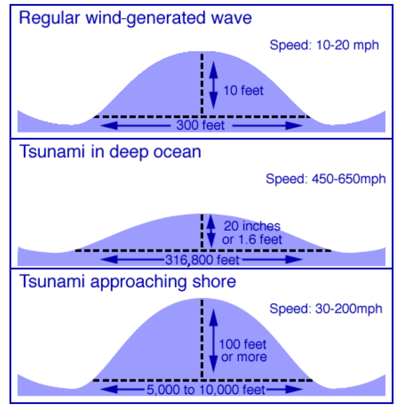


Figure 17-2 Wind-generated Waves vs. Tsunami Waves

Definition

"The term tsunami (soo-NAH-mee) is a Japanese word meaning harbor wave. A tsunami is a series of waves with a long wavelength and period (time between crests) generated by a large, impulsive displacement of sea water", from an earthquake or large landslide into or under the water surface. Sometimes mislabeled as tidal waves, tsunamis have no relation to daily ocean tides. Wind-generated waves differ from tsunami waves in that wind generated waves have periods (time between crests) between 5 and 15 seconds while tsunami wave periods range between 5 and 60 minutes in length (Figure 17-2). Wind-generated waves also break when they enter shallow water and lose energy offshore, while tsunami waves "act more like a flooding wave", in which a 20 foot tsunami wave will result in a 20 foot rise in sea level.[102] Tsunami waves from an offshore earthquake radiate outward from their source much like ripples on a pond, with the resulting waves striking the adjacent shoreline within minutes. The waves can also speed across the ocean at more than 600 miles per hour to strike distant shores.

History

"On the Pacific Coast, from southern British Columbia to northern California, people and property are at risk from distantly and locally generated tsunamis. Recent studies indicate that about a dozen very large earthquakes (with magnitudes of 8 or more) have occurred in the Cascadia Subduction Zone located off of the coast of Washington. Computer models indicate

Figure 17-3 Damage from the Prince William Sound Tsunami in Kodiak, Alaska; March 28, 1964

that tsunami waves generated by these local events might range from 5 to 55 feet in height and could affect the entire coastal region."

The most recent tsunami to strike Washington's coast was on March 28, 1964 and was generated by the 9.2 magnitude earthquake that struck Alaska's Prince William Sound. (Figure 17-3) The first wave of the tsunami generated from this earthquake struck Crescent City, California nine feet above the tide level, the second wave, 29 minutes later, was 6 feet above tide level, the third wave was 11 feet above tide level, and the fourth wave was 16 feet above tide level. The third and fourth wave in Crescent City killed 11 people with damage estimates between $7.4 million and $16 million (1964 dollars) dollars. This same tsunami affected areas all along the Pacific Coast from Alaska to California. In Washington, the tsunami caused an estimated $105,000 (1964 dollars) worth of damage to the Washington coast. Although the 1964 event was the most recent tsunami to reach the coast of Washington, recent geologic investigations indicate that large tsunamis have struck the coast many times in the last few thousand years.

The world's worst tsunami to date was generated by a magnitude 9.3 (discrepancies for this earthquake's magnitude are between 9.0-9.3) earthquake off the west coast of northern Sumatra, Indonesia, on December 26, 2004. The resulting tsunami killed more than 297,000 people, more people than any other tsunami in recorded history and displaced more than 1,126,000 people from their homes. The economic loss from the earthquake and resulting tsunami exceeded over $10 billion dollars (2004 dollars).[103] While a massive relief effort on a global scale came forth to help those affected by this event, the hardest hit areas are still in a recovery and rebuilding phase.

Assessment

"U.S. coastal communities are threatened by tsunamis that are generated by local earthquakes and distant earthquakes."[104] Local tsunamis give residents only a few minutes to seek safety, while tsunamis of distant origins give residents more time to evacuate threatened coastal areas but also increase the need of timely and accurate assessments of a potential tsunami to avoid the cost of false alarms. "The Cascadia Subduction Zone (Figure 17-4) threatens California, Oregon, and Washington with devastating local tsunamis that could strike the coast within minutes. There is increasing geological and seismological

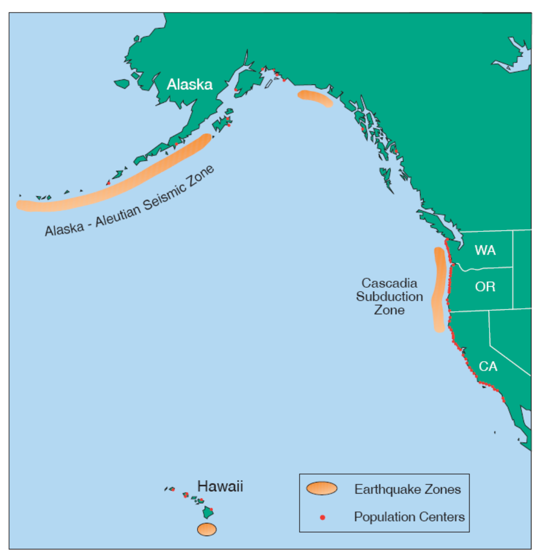


Figure 17-4 Tsunami Hazards for the West Coast of the United States

evidence that: earthquakes of Richter scale magnitude 8 and more have previously occurred in this region; at least one segment of the subduction zone may be approaching the end of a seismic cycle culminating in such an earthquake; and, these earthquakes have generated tsunamis that have caused extensive flooding along the coastlines of Washington, Oregon and California. Recent articles indicate that the probability of a Cascadia earthquake occurring is comparable to that of large earthquakes in southern California (i.e. 35% probability of magnitude of 8 or above between 1995 and 2045)." The Alaska and Aleutian Seismic Zone has also been recognized as a region with very high seismic potential, with earthquakes from this zone resulting in tsunamis that could strike the Washington coast as seen in the previously mentioned 1964 Alaska earthquake.

As part of the U.S. National Tsunami Hazard Mitigation Program (NTHMP) the National Oceanic and Atmospheric Association (NOAA) set goals to: reduce the loss of life and property in U.S. coastal communities, reduce false alarms and the resulting high economic cost of unnecessary evacuations, lessen the physical risk to the population during evacuations, and reduce the loss of public confidence in the tsunami warning system. To achieve these goals NOAA developed deep-ocean tsunameters for early detection, measurement, and real-time reporting of tsunamis in the open ocean. The tsunameters were developed by Project DART (Deep-ocean Assessment and Reporting of Tsunamis) at NOAA's Pacific Marine Environmental Laboratory (PMEL) located in Seattle. The DART systems (Figure 17-5) have been deployed near regions with a history of tsunami generation to ensure measurement of the waves as they propagate towards threatened U.S. coastal communities and to acquire data critical to real-time forecasts.

Figure 17-5 The first DART (Deep-ocean Assessment and Reporting of Tsunami) Detection Buoy

The wide-scale loss of human life, destruction, and economic impact from the December 2004 tsunami resulted in an influx of government spending toward tsunami warning systems and community education and training for U.S. coastal communities that could potentially be impacted by a tsunami event. "In 2005, the President's tsunami-warning initiative directed $37.5 million dollars to the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) to improve the United State's domestic tsunami detection and warning system."[105]

This push in government spending has resulted in increased capability for the USGS to detect earthquakes and enabled the NOAA to further extend the DART tsunami detection buoy network to have greater capability in detecting deep-ocean tsunami waves to give coastal communities the necessary time needed to evacuate.

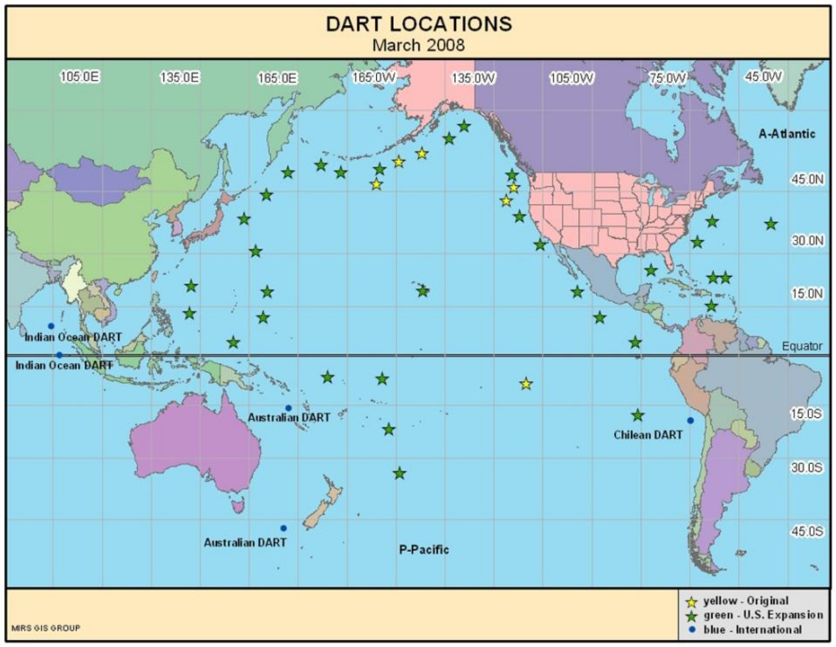


Figure 17-6 Location of NOAA DART (Deep-Ocean Assessment and Reporting) Tsunami Instruments, as of March 2008

This network now consists of a total of 39 deep-ocean detection and assessment buoys (Figure 17-6). "When a tsunami event occurs, the first information available about the source of the tsunami is based only on the available seismic information for the earthquake event. As the tsunami wave propagates across the ocean and successively reaches the DART systems (buoys), these systems report sea level information back to the Tsunami Warning Centers, where the information is processed to produce a new and more refined estimate of the tsunami source. The result is an increasingly accurate forecast of the tsunami that can be used to issue watches, warnings, or evacuations."[106]

Figure 17-7 Tsunami Evacuation and Hazard Zone Signs

This initiative toward recognizing tsunamis to issue warnings to affected communities has spread to educating communities on the tsunami potential, signs and signals a tsunami may be approaching, and measures to get out of harm's way should an event occur. Tsunami hazard zone signs are "intended to be posted at Pacific coast access points or other low-lying areas that would clearly be vulnerable to a large, locally generated tsunami."

Figure 17-8 NOAA's National Weather Service TsunamiReady™ Program

Tsunami evacuation route signs (Figure 17-7) are used to "designate that evacuation routes established by local jurisdictions in cooperation with emergency management officials."[107]

In addition to warning signs, NOAA's National Weather Service (NWS) has established a TsnuamiReady™ (Figure 17-8) program that "gives communities the skills and education to survive a tsunami before, during and after an event".[108]

To meet criteria for this program communities must: establish a 24-hour warning point and emergency operations center, have more than one way to receive tsunami warnings and to alert the public, promote public readiness through community education and the distribution of information, and develop a formal tsunami plan, which include holding emergency exercises. Currently, Washington State has 3 communities (Long Beach, Ocean Shores, and Aberdeen), 3 counties (Pacific, Grays Harbor, and Clallam), and 1 Indian Nation (Quinault Indian Nation) that have been granted the TsunamiReady™ status (Figure 17-9).

Figure 17-9 TsunamiReady™ Members in Washington, as of Feb. 6, 2008 (Counties in Purple & Communities and Indian Nations represented by light blue dots and light blue outline)

While no amount of planning, education and preparedness can make a community tsunami proof, personal and community preparedness can greatly reduce the amount of lives lost and property destroyed in the event that a tsunami strikes Washington's coast.

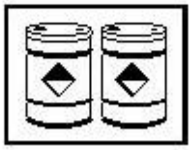
Internet Resources

NOAA/National Weather Service, TsunamiReady™ Program, www.tsunamiready.noaa.gov/

NOAA/PMEL, Center for Tsunami Research – DART (Deep-ocean Assessment and Reporting Tsunami)
http://nctr.pmel.noaa.gov/Dart/index.html

NOAA National Data Buoy Center
www.ndbc.noaa.gov/dart.shtml

Umatilla Chemical Depot



Frequency	50+ yrs
People	1-1,000
Economy	1% GDP
Environment	
Property	

Risk Level

- Frequency – There has not been a serious incident since 1944.
- People – A worst-case scenario could include hundreds of deaths.
- Economy – The State economy could lose billions of dollars from embargos on agricultural products if international markets suspect wide spread contamination.
- Environment – There are no known sensitive or endangered species of plant or animal in the potential exposure area of the Umatilla Chemical Weapons Depot that would cause at least 10% of a single species or habitat to be eradicated in the event of a release.
- Property – Due to the remote location of the Umatilla Chemical Weapons Depot and the limited amount of structures in the Protective Action Zones (PAZ) in Washington, it is unlikely that there would be severe property damage in an event.

Hazard Area Map

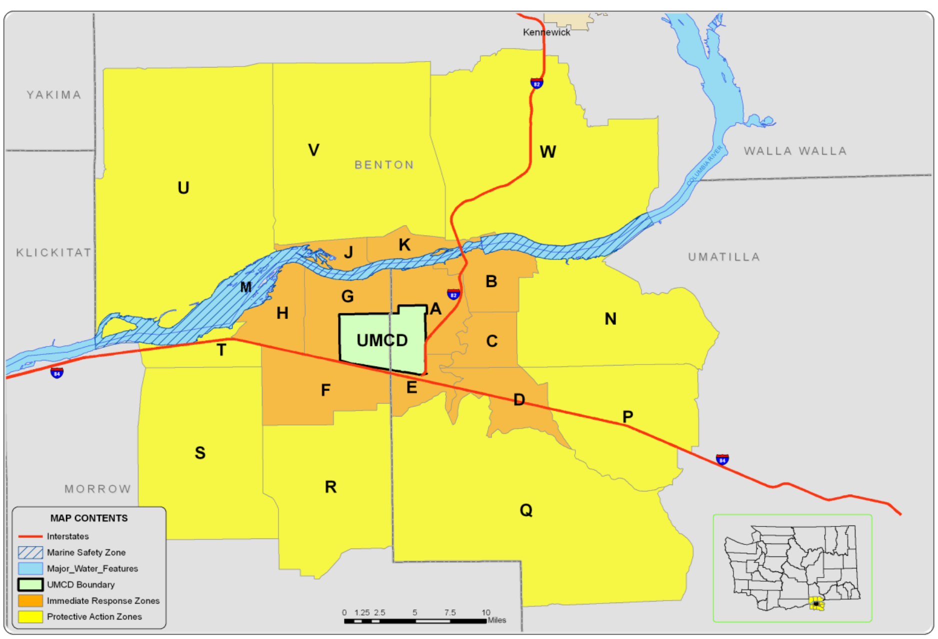


Figure 18-1 Umatilla Chemical Depot Emergency Zones

The Umatilla Chemical Depot (UMCD) is located in Oregon, 10 miles south of the Washington border. In the map (Figure 18-1) the orange Immediate Response Zones (IRZ) J and K are located in Washington. The yellow Protective Action Zones (PAZ) U, V and W are also located in Washington (Figure 18-1). All of the IRZs and PAZs are located in Benton County, which also has the primary responsibility for the Marine (M) zone on the Columbia River. The inset map shows the location of UMCD in relation to the rest of Washington.

Definition

"Chemical Weapons" means the following, together or separately:

(a) Toxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes;

(b) Munitions and devices, specifically designed to cause death or other harm through the toxic properties of those toxic chemicals specified in subparagraph (a), which would be released as a result of the employment of such munitions and devices;

(c) Any equipment specifically designed for use directly in connection with the employment of munitions and devices specified in subparagraph (b).

"Toxic Chemical" means:

Any chemical, which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere.[109]

History

Military planners envisioned the U.S. Army Umatilla Ordnance Depot as a munitions and general supply storehouse years before it became a reality in 1941. However, the onslaught of World War II assured and then hastened the Depot's construction.

Figure 18-2 UMCD Entrance

In 1940, the Army selected a 16,000-acre plot in northeastern Oregon for the construction of a new arsenal. Construction work began in January 1941 and 10 months later on, Oct. 14, 1941 officials dedicated the depot and named it for the Umatilla Indian tribe (Figure 18-2).

Thirty-five million dollars and 7,000 workers transformed the prairie site into a complex of warehouses, munitions magazines, shops, and office buildings connected by a web of paved roads and railroad tracks – essential elements for shipping and receiving.

Ordnance, as many local residents called it then, was ready when its first munitions shipment arrived Oct. 27, 1941. After the attack on Pearl Harbor six weeks later, Dec. 7, 1941, Depot workers went on round-the-clock shifts to ship, receive, store, and care for items. In March 1944, six depot workers – five men and one woman – lost their lives when a conventional ammunition storage igloo exploded during a night shift. Today, a monument created from that igloo's largest remaining piece stands on the depot's parade field as a tribute to them.

During its now 60-year history, Umatilla has grown to almost 20,000 acres as it expanded to support other war efforts such as the Korean Conflict, Vietnam War, Grenada, and Panama. More recently, Umatilla repeated its ammunition and general supply support role as Operation Desert Shield turned to Desert Storm. Workers shipped more than 10,000 tons of conventional ammunition during Desert Storm's first 18 days, with 223 shipments and 19,371 tons in all before the conflict ended.

Besides its conventional ammunition and general supply missions, the Depot received a new mission in 1962 – receiving and storing chemical ammunition. Between 1962 and 1969, the depot received various types of ammunition with the chemical nerve agents VX and GB, and the mustard blister agent HD, including 155MM (Figure 18-3) and 8-inch projectiles; M55 rockets (Figure 18-4); M23 mines; 500- and 750-pound bombs; spray tanks; and one-ton containers. Today the ammunition awaits destruction. Meanwhile the Depot continues safely and securely storing it in storage structures commonly called "igloos," (Figure 18-5) guarded round the clock by the Depot's government civilian and military security force.

Figure 18-3
155mm Projectile

Figure 18-4
M55 Rocket

While igloos vary in size, most are 80 feet long, about 26 feet wide and almost 13 feet high. They are concrete structures with steel rebar, have steel doors, and are covered with a minimum of 2 feet of earth. Each igloo has a lightning protection system. Inside temperatures range from 50-60 degrees Fahrenheit year round.

Figure 18-5 Chemical Weapons Storage Igloo

In the mid-1980s, Congress directed the Army to dispose of the nation's chemical weapons stockpile. On April 25, 1997, the Army ratified the Chemical Weapons Convention, an international treaty mandating stockpile destruction.

In June 1997, construction started on the Umatilla Chemical Agent Disposal Facility – the facility that will be used to destroy the Depot's stockpiled chemical munitions (Figure 18-6). Construction was substantially completed in August 2001. Disposal operations at the Depot began on September 7, 2004. Since this time, there have been 12 munitions disposal campaigns successfully completed. In November 2008, the Depot destroyed its last nerve agent ordinance, with only mustard blister agent remaining to be destroyed. Today the depot's sole remaining mission is too safely and securely stores its chemical ammunition stockpile.[110]When the Depot's chemical munitions destruction mission is complete, the disposal plant will be thoroughly cleaned and disassembled according to environmental permits. The Umatilla Chemical Depot is slated for closure once all munitions and chemicals agents have been destroyed, per the 2005 Base Realignment and Closure (BRAC) law[111].

Figure 18-6 Umatilla chemical Agent Disposal Facility

UMCD/UMCDF Disposal Campaigns[112]

- 4 GB (sarin-filled) bulk containers or "ton containers" completed Jan. 5, 2006. This was a Non-Stockpile Chemical Materiel Project (NSCMP) mission.
- 27 GB 500-pound bombs completed May 18, 2006.
- 2,418 GB 750-pound bombs completed June 9, 2006.
- 91,442 GB rockets and warheads completed Aug. 9, 2006.
- 14,246 GB 8-inch diameter artillery projectiles completed Jan. 3, 2007.
- 47,406 GB 155mm diameter artillery projectiles completed July 8, 2007.
- One VX bulk container or "ton container" completed Nov. 26, 2007. This was a Non-Stockpile Chemical Materiel Project (NSCMP) mission.
- 156 VX aircraft-mounted spray tanks completed Dec. 24, 2007.
- 14,519 VX rockets and warheads completed Jan. 23, 2008.
- 32,313 VX 155mm projectiles completed June 27, 2008.
- 3,752 VX 8-inch projectiles completed August 6, 2008.
- 11,685 VX land mines completed November 5, 2008.

<u>Assessment</u>

The Chemical Stockpile Emergency Preparedness Program (CSEPP) was developed to provide assistance and oversight to the activities at Umatilla Chemical Depot. Warning the public is a critical component of any emergency program. Because of the need for fast implementation of protective actions, CSEPP relies on a public warning system that uses outdoor sirens (Figure 18-7) with voice address capability, indoor alert radios (Figure 18-8), and programmable message boards (Figure 18-9) along major roads, to ensure that people will receive a prompt warning regardless of their location. The system works in conjunction with the Emergency Alert System, a national system of commercial radio and television stations to provide emergency warnings.[112]

Figure 18-7
Outdoor Siren

Figure 18-8
Alert Radio

Figure 18-9
Message Board

Since the mid-1990's IEM (Innovative Emergency Management) has developed and continually enhanced D2-Puff™ under a contract with the U.S. Army Soldier Biological and Chemical Command (SBCCOM) now named the Chemical Materials Agency (CMA). D2-Puff™ is an advanced chemical dispersion model designed for hazard prediction and to assist emergency response to accidents or incidents involving chemical weapons. It is one of only three DOD-approved chemical and biological dispersion models. The D2-Puff™ model is incorporated within WebPuff, a completely browser-based emergency management system that is used daily by the U.S. Army (Figure 18-10).

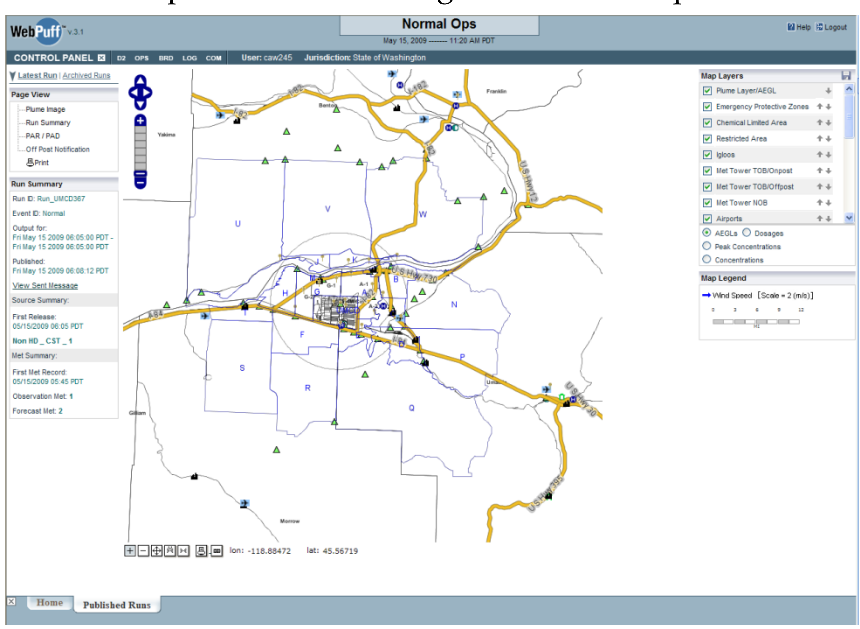


Figure 18-10. WebPuff internet-based emergency management system

The dispersion model, D2-Puff, that is ran using inputs from meteorological data from on-and off-post towers including effects of forecast weather changes and terrain effects along. This model calculates estimated dosage, concentration, and AEGLs in addition to potential in-shelter exposure.

Internet Resources

U.S. Army Chemical Materials Agency CSEPP
http://www.cma.army.mil/csepp.aspx

Umatilla/Morrow Counties CSEPP
http://www.csepp.net/

Washington State Department of Health CSEPP
http://www.doh.wa.gov/EHP/oehas/eha_csepp.htm

Benton County Emergency Services CSEPP
http://www.bces.wa.gov/csepp%20new.htm

Washington Military Department Emergency Management Division CSEPP
http://emd.wa.gov/training/training_csepp.shtml

Global Security Umatilla Chemical Depot
http://www.globalsecurity.org/wmd/facility/umatilla.htm

Oregon Department of Environmental Quality Chemical Demilitarization Program
http://www.deq.state.or.us/umatilla/cdp.htm

Umatilla Comprehensive Monitoring Program
http://www.umatilla-cmp.org/

IEM Homeland Security and Emergency Management
http://www.ieminc.com/FeaturedSolution-GIS.php

Volcano (Lahar & Ash Fall)

LAHAR	
Frequency	10-50 yrs
People	1,000-10,000
Economy	1-2% GDP
Environment	
Property	$1B+

Risk Level – Lahar

- Frequency – Lahar incidents do not occur annually.
- People – With the early detection and advanced warning of increased probability and detection of a lahar. Significant loss of life in such an event can be avoided. Due to the size of the communities in the potential hazard zones for a lahar event, a large amount of people may be affected.
- Economy – In a catastrophic lahar, the economy can be expected to suffer severely in the beginning stages of the response and recovery. It can also suffer in the end if major infrastructure is damaged and areas affected by the lahar are not available for redevelopment for years to decades as river channels get reestablished and a lot of sediment is transported downstream.
- Environment – According to subject matter experts, the threshold for inclusion of this category is unlikely to be met in a single lahar.
- Property – State and international statistics indicate that there is the potential for property damage from a large lahar to exceed $1 billion dollars in damage.

ASH FALL	
Frequency	10-50 yrs
People	
Economy	1-3% GDP
Environment	
Property	$1B+

Risk Level – Ash Fall

- Frequency – Volcanic ash fall incidents do not occur annually.
- People – An incident of volcanic ash fall is unlikely to result in significant losses of life.
- Economy – An incident of volcanic ash fall has the potential to affect the economy of Washington from moderate to severe depending on the amount of ash dispensed over the state and the resources needed to restore normal business operations following such an incident.
- Environment – An incident of volcanic ash fall is unlikely to result in the loss of 10% of a single species or habitat.
- Property – State and international statistics indicate that there is the potential for property damage from a volcanic ash fall incident to exceed $1 billion dollars

Hazard Area Maps

Volcanoes

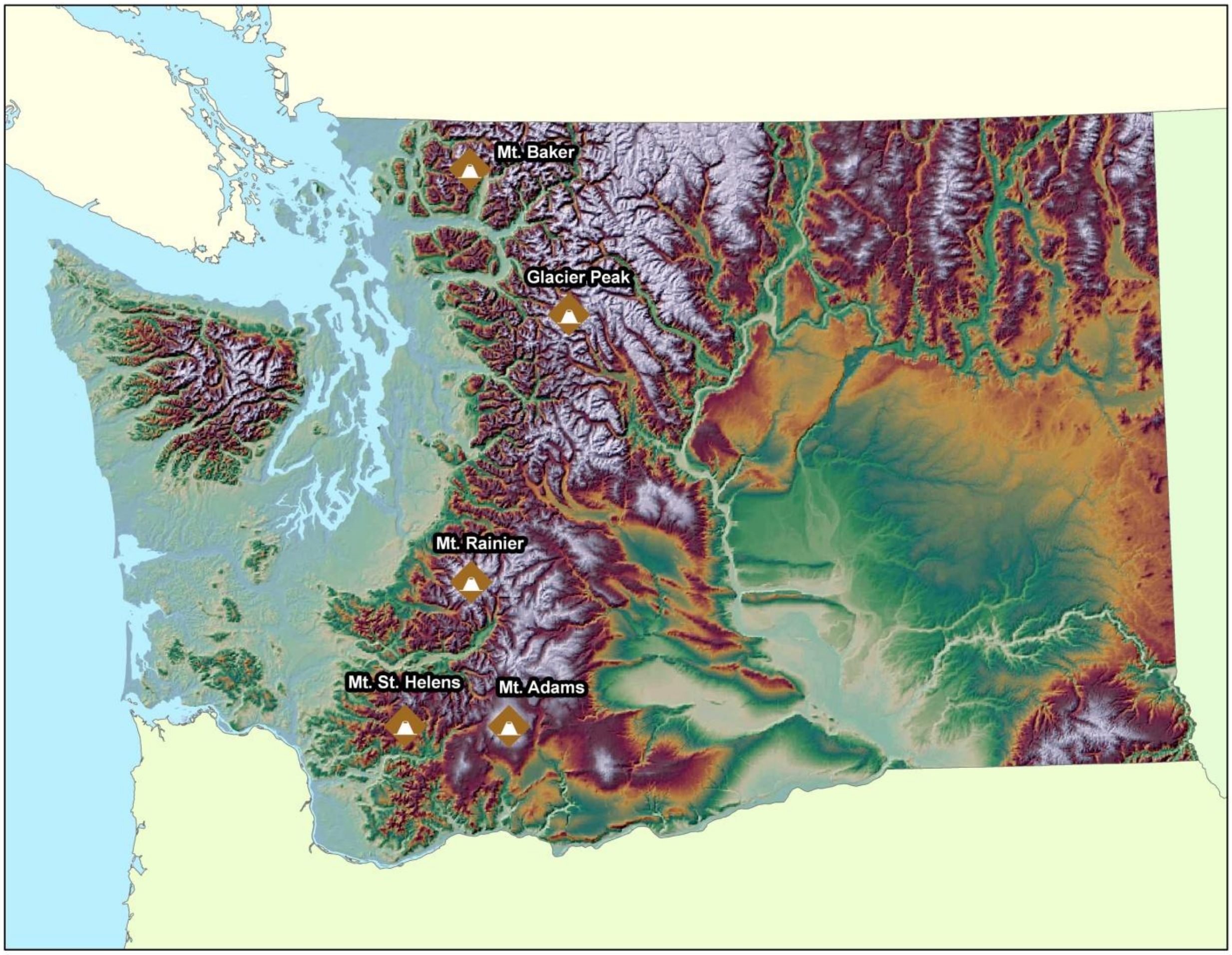


Figure 19-1 Volcano locations in Washington State. These volcanoes are all located along the Cascade Range and are considered active with varying levels of activity, eruption potential, and hazards.

Hazard Area Maps (cont.)

Lahar Zones

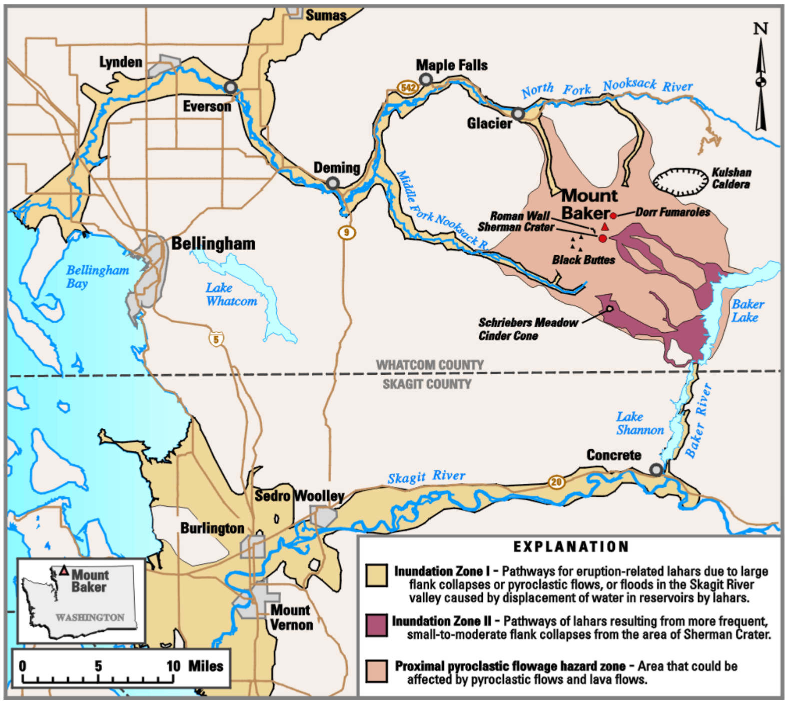


Figure 19-2 Hazard Zones for Lahars, Pyroclastic Flows and Lava Flows at Mount Baker.

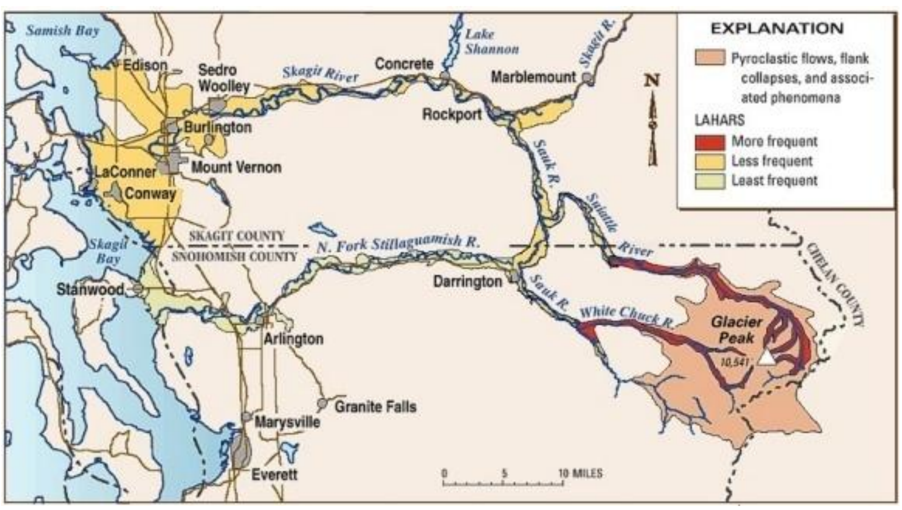


Figure 19-3 Areas at Risk of Lahars, Lava Domes, Pyroclastic Flows and Associated Phenomena from Glacier Peak.

Hazard Area Maps (cont.)

Lahar Zones

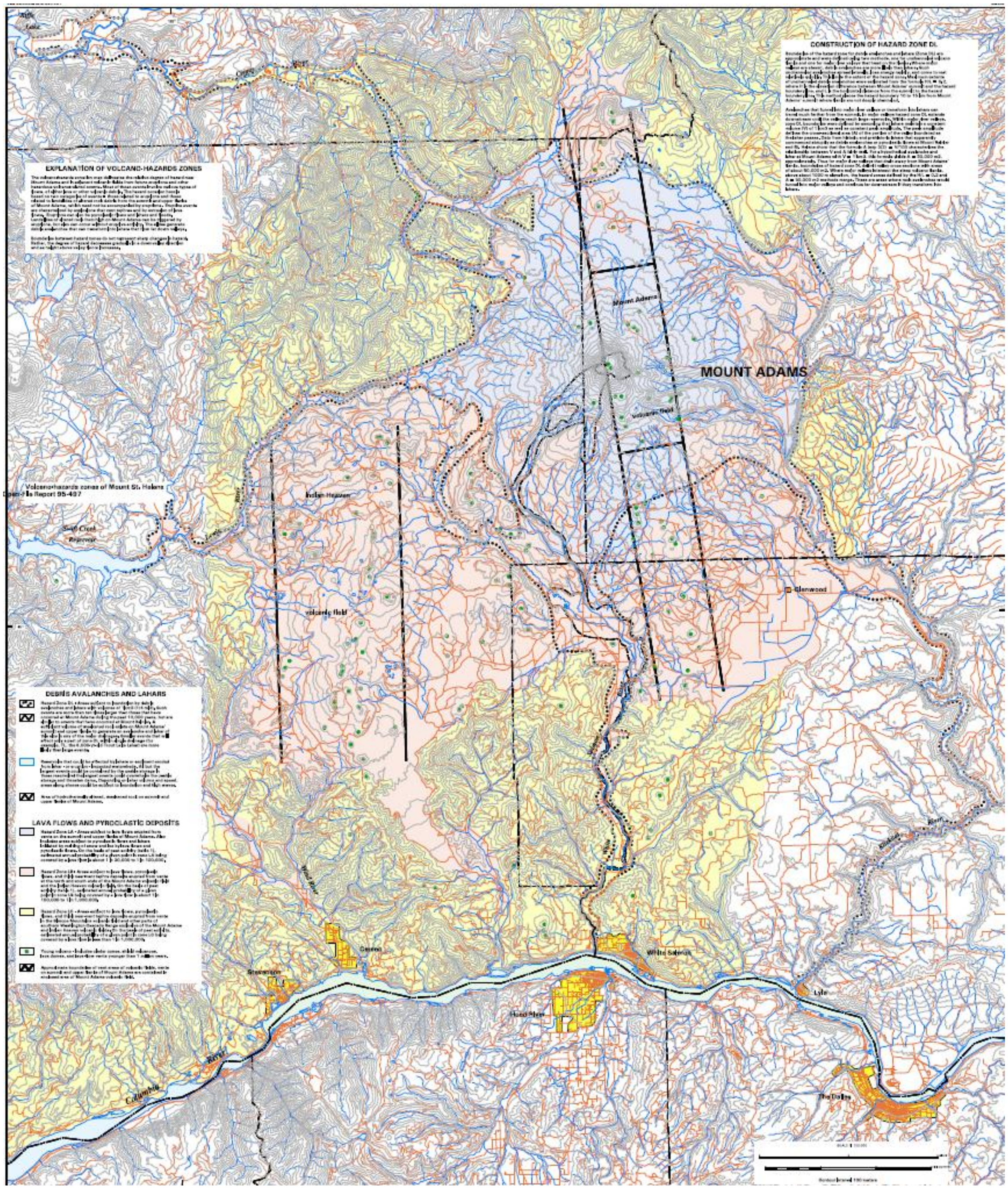


Figure 19-4 Volcano- Hazard- Zonation Map of Mount Adams, Washington. Colored zones on the map indicate hazard zone areas.

Hazard Area Maps (cont.)

Lahar Zones

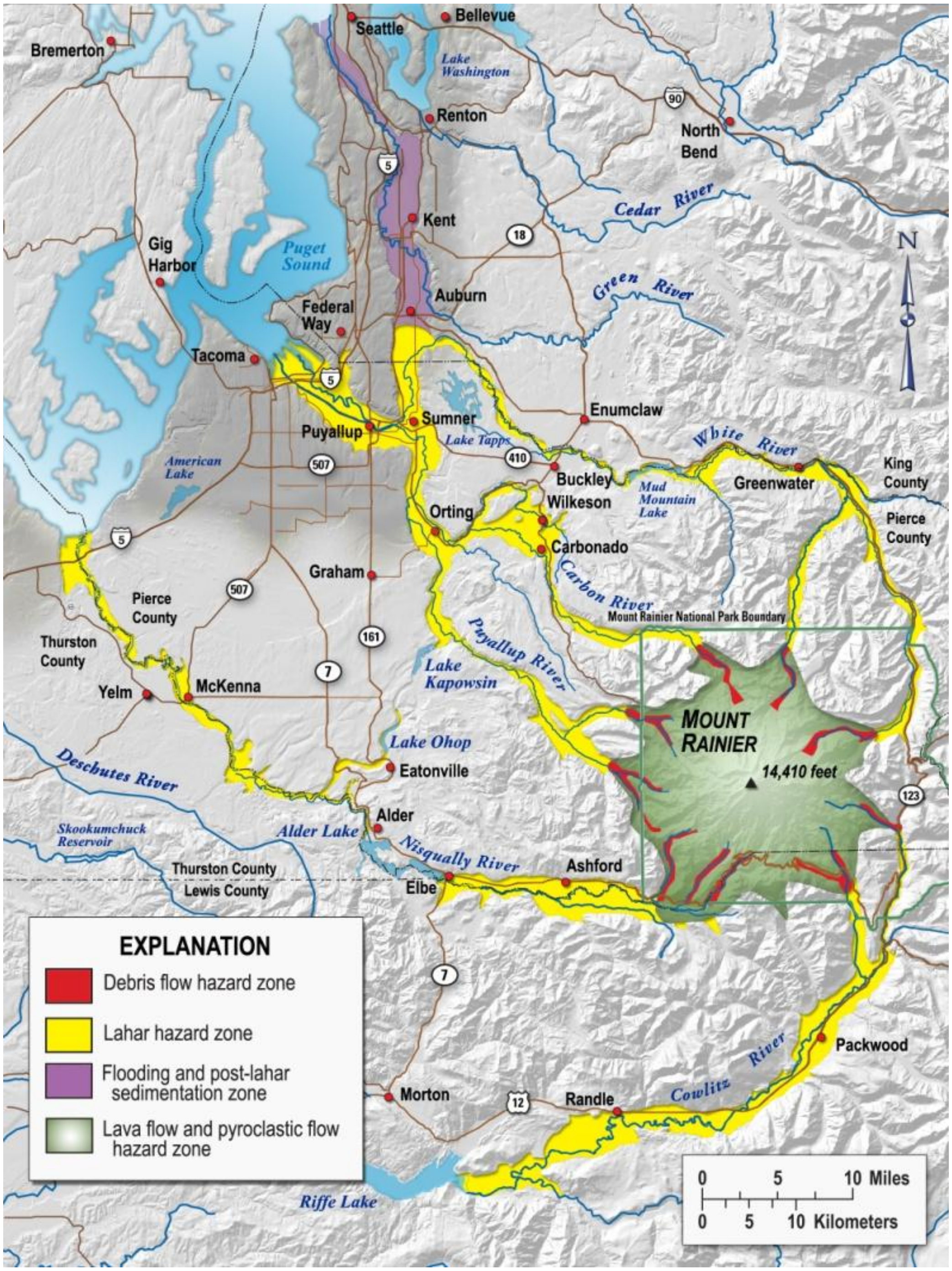


Figure 19-5 Hazard Zones for Lahars, Lava Flows, and Pyroclastic Flows from Mount Rainier. The map shows areas that could be inundated if events similar in size to those of the past occurred today. Lahar hazard is not equal in all valleys. Puyallup Valley is the most susceptible to lahars caused by flank collapse. Risk to individual drainages will be refined as scientists learn more about the volcano.

Lahar Zones

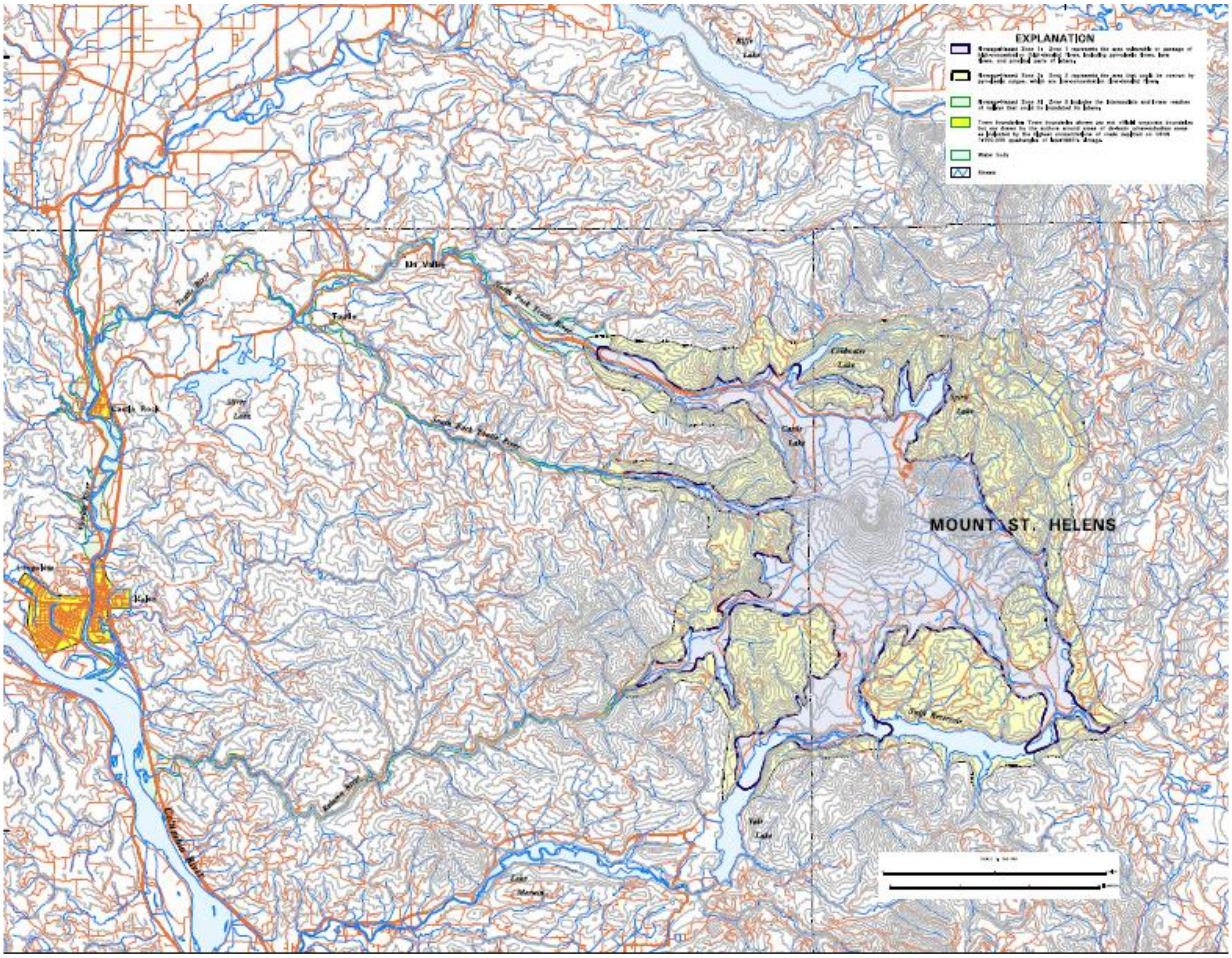


Figure 19-6 Volcano Hazard Zones of Mt. St. Helens

Hazard Area Maps (cont.)

Ash Fall

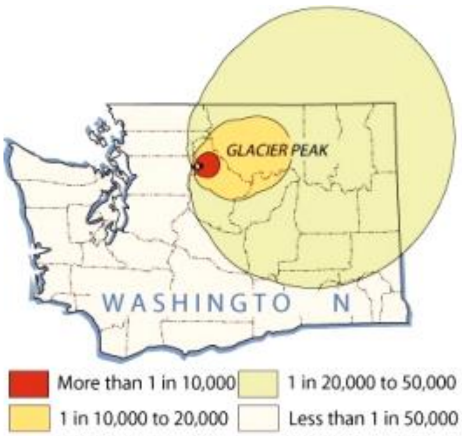


Figure 19-7 Annual probability of tephra fall exceeding 0.5 inch thick from Glacier Peak. Communities east of the volcano are more susceptible to tephra fall because the wind is normally from the west. Glacier Peak has produced large tephra eruptions, but not frequently.

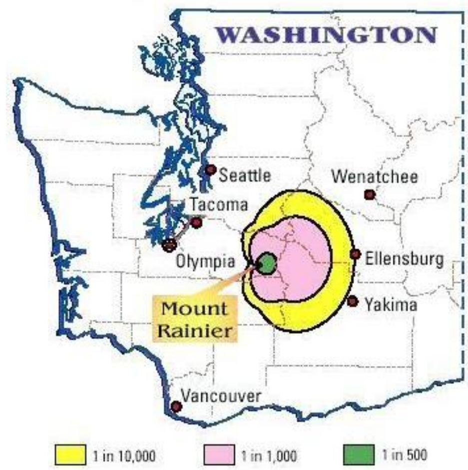


Figure 19-8 Probability of tephra accumulation for Mount Rainier. Map shows the annual probability that volcanic ash will be deposited to a thickness of 1/3 inch or more from an eruption of Mount Rainier. Volcanic ash of this thickness or less, can cause disruption of ground and air transportation, and can cause damage to electronics or machinery.

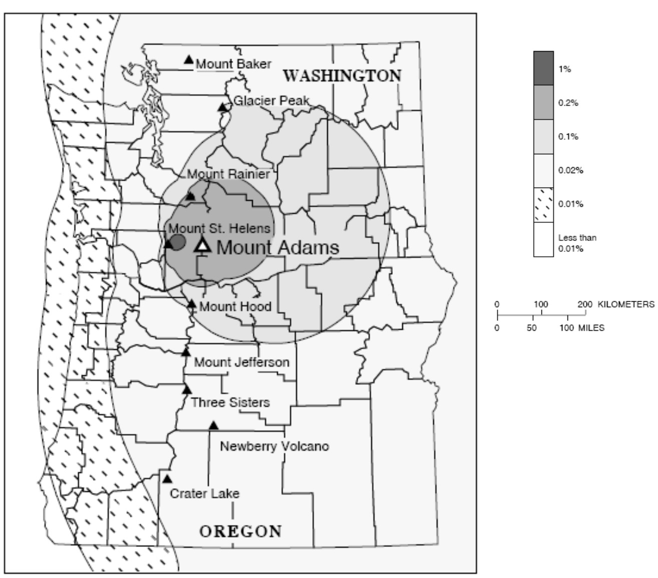


Figure 19-9 Annual probability of 1 centimeter or more tephra accumulation in Washington and Oregon from major Cascade volcanoes

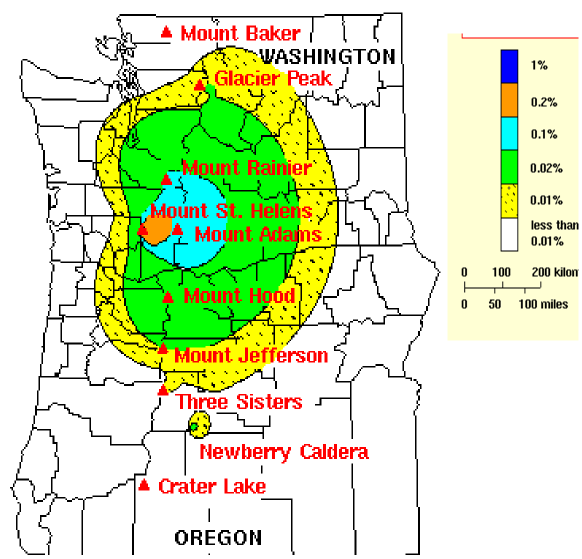


Figure 19-10 Annual probability of 10 centimeters or more of tephra accumulation from a major Cascade volcano in Washington and/or Oregon.

Definitions

A volcano is "a vent in the earth's surface through which magma (molten rock) and associated gases erupt".[113] Scientists generally consider a volcano active if it is currently erupting or shows signs of unrest, such as unusual earthquake activity or significant new gas emissions. Many scientists also consider a volcano active if it has erupted in historic time. Since the span of recorded history varies from region to region across the globe, this may affect which volcanoes are deemed active and inactive. "Dormant volcanoes are those that are not currently active, but could become restless or erupt again." Extinct volcanoes are those that scientists consider are unlikely to erupt again, but whether a volcano is truly extinct is often quite difficult for scientists to determine.

A lahar "is an Indonesian word for a rapidly flowing mixture of rock debris and water that originates on the slopes of a volcano. Lahars are also referred to as volcanic mudflows or debris flows".[114] These events form in a number of ways, most often by the rapid melting of snow and ice by pyroclastic (rock fragmentation resulting from volcanic ejection[115]) flows, intense rainfall on loose volcanic rock deposits, breakout of a lake dammed by volcanic deposits, and as a result of debris avalanches. (Figures 19-2 to 19-6 show hazard areas for lahar.)

"Small jagged pieces of rocks, minerals, and volcanic glass the size of sand and silt (less than 1/12" or 2 mm in diameter) erupted by a volcano are called volcanic ash."[116] Explosive eruptions in which volcanic ash is formed occur when "gases dissolved in molten rock (magma) expand and escape violently into the air" as well as when water gets heated by magma and suddenly flashes into steam. "Volcanic ash is hard, does not dissolve in water, is extremely abrasive, and conducts electricity when wet." Because volcanic ash can conduct electricity, it has the potential to cause short circuits and the failure of electronic components, especially high-voltage circuits and transformers. (Figures 19-7 to 19-10 show hazard areas for ash fall.)

History

The Cascade Range extends from northern California through Washington. Within this mountain range, there exist over a dozen potentially active volcanoes, five of which are in Washington - Glacier Peak, Mount Baker, Mount Rainier, Mount Adams, and Mount St. Helens. The active volcanoes in Washington have a varied history of activity and eruptions.

Mount Baker
Mount Baker last erupted in the mid-1800s for the first time in several thousand years.

Volcanic activity at steam vents in Sherman Crater, near the volcano's summit, increased in 1975 and to this day is still strong; but there is no evidence that an eruption is imminent

Glacier Peak

Glacier Peak has experienced four eruptive periods during the past four thousand years. About thirteen thousand years ago a powerful series of eruptions from this volcano deposited volcanic ash as far away as Wyoming.

Mount Adams

Mount Adams has produced few eruptions during the past several thousand years. The most recent activity for this volcano occurred with a series of small eruptions about a thousand years ago.

Mount Rainier

Mount Rainier has produced numerous eruptions and lahars in the past four thousand years. Rainier is also capped by more glacial ice than all other Cascade volcanoes combined. Hot, acidic volcanic gases and water making it especially prone to landslides and lahars have weakened parts of the steep slopes of Rainier.

Mount St. Helens

Mount St. Helens has been the most frequently active volcano in the Cascade Range during the past four thousand years, producing many lahars and a wide variety of eruptive activity. Mount St. Helens recently ended an eruption that extended from October 2004 to early 2008. It resulted in gas and steam explosions from inside the crater along with extensive lava dome building.

Prior to its 2004-2008 eruption, Mount St. Helens experienced many periods of explosive eruptive activity and extrusion of lava domes and flows. The most notable incident was the eruption in the spring of 1980. Following two months of earthquakes, bulging north flank, and minor explosions, Mount St. Helens erupted on May 18, 1980 in one the most devastating volcanic eruptions of the 20th Century. "Within 15 to 20 seconds of a magnitude 5.1

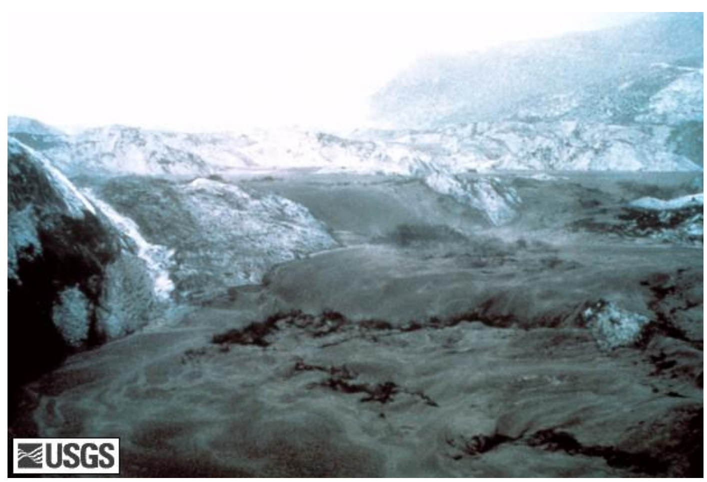


Figure 19-11 Mount St. Helens Lahar May 1980

earthquake at 8:32 am, the volcano's bulge and summit slid away in a huge landslide – the largest sub-aerial one on Earth in recorded history."[117] Although less than 0.1 cubic mile of molten rock (magma) was erupted, 57 people died, and damage exceeded one billion dollars.

This eruption produced several lahars that poured down into river valleys, ripping trees from their roots and destroying roads and bridges in their path. The largest and most destructive (Figure 19-11) of the lahars was formed by water seeping from inside the huge landslide deposit. This sustained flow of water-eroded material from both the landslide and the channel of the North Fork Toutle River. The lahar increased in size as it flowed downstream, resulting in the destruction of homes and bridges, eventually reaching its maximum size in the Cowlitz River, fifty miles downstream from the volcano. The resulting lahars from this cataclysmic eruption damaged 27 bridges, nearly 200 homes, and severely altered the environmental landscape that previously surrounded the volcano.

The 1980 Mount St. Helens eruption blasted an enormous cloud of gases and ash more than 60,000 feet into the air. This eruption cloud blew 520 million tons of ash eastward across the United States and put the city of Spokane, 250 miles away, under complete darkness. Detectable amounts of ash could be found over an area of approximately 22,000 square miles. The falling ash fell on homes, farms, machinery, and roads. Ash prevented traveling throughout much of eastern Washington because of poor visibility, slippery roads, and ash-damaged vehicles resulting in over ten thousand people being stranded and isolating many smaller communities in the area. It is estimated that over $1 billion dollars (1980 dollars) in property damage and economic losses were caused by the Mount St. Helens eruption.

Assessment

Because the population is rapidly expanding in the Pacific Northwest, the volcanoes of the Cascade Range in Washington, Oregon, and California are considered some of the most dangerous in the United States.[118] When volcanoes of the Cascade Range erupt, high-speed avalanches of hot ash and rock (pyroclastic flows), lava flows, and landslides can devastate areas ten or more miles away. Lahars can engulf valleys more than fifty miles downstream. Volcanic ash can fall hundreds of miles away from the site of eruption and can affect the local agriculture, livestock, people, businesses, and infrastructure of the area, resulting in millions of dollars in economic losses and property damage. In addition, aircraft in flight are vulnerable to rifting clouds. The risk of volcanic hazards from Washington volcanoes varies and mostly depends on an individual volcano's likely effect on people, economy, environment, and property if it were to erupt.

Glacier Peak is the most remote of the five active volcanoes in Washington and is not prominently visible from any major population center[119]. Due to this feature Glacier Peak's attractions as well as its hazards tend to be overlooked.[121] Lying within 70 miles of Seattle, Glacier Peak rises just a few thousand feet above a snowy saw toothed skyline; yet this volcano has been one of the most active and explosive of Washington's volcanoes.[121] Glacier Peak has erupted repeatedly during at least six episodes in the past 15,000 years.[121] Two its eruptions were among the largest in Washington during this time period. Glacier Peak's eruptive episodes are typically separated by several hundred to a few thousand years.[121]

Figure 19-12 Lahar Deposit Produced by a Prehistoric Eruption of Glacier Peak.

Thus, in any given year, the probability of a new episode beginning is roughly one in a thousand – it is unlikely that we will see an eruption within our lifetimes.[121] If one does take place, its impact would vary dramatically in different geographic areas depending on the size of the eruption, wind direction, and type of hazard (ash, lahar, lava dome, etc.) produced.[121]

In undeveloped areas near the volcano, the landscape would be severely altered by lava domes, pyroclastic flows, ash clouds, lahars, and associated phenomena.[121] In river valleys located downstream, lahars could block transportation routes, destroy or severely damage bridges and highways, damage or destroy houses and farmland, choke river channels with mud and debris and increase the severity of floods for years or even decades after an eruption.[121] Potential lahars are most likely to affect the White Chuck and upper Suiattle River Valleys (Figure 19-12).[121]

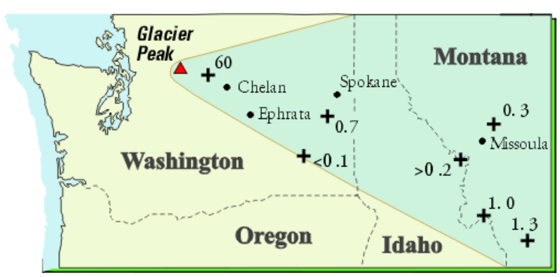


Figure 19-13 Thickness of Ash from Glacier Peak during a Series of Eruptions about 13,100 years ago. Light blue indicates approximate area covered by ash (spot thickness in inches) during these eruptions.

Less likely, but potentially more damaging would be a lahar that reaches the Sauk and Skagit River valleys due to their greater population and infrastructure.[121] In areas located downwind from the volcano, even a small tephra eruption (an eruption that produces ash) could disrupt air and ground transportation as well as cover towns in ash.[121] A large tephra eruption (comparable to Glacier Peak's largest) (Figure 19-13) would have a more widespread effect and could deposit enough ash to collapse roofs in nearby towns downwind.[121] Owing to prevailing wind patterns, ash fall during future eruptions from Glacier Peak can be expected to chiefly impact communities that lie east of the volcano.[121] But ash fall could affect communities in any direction from the volcano depending on wind patterns during an eruption.[121]

Mount Baker lies to the northwest of Glacier Peak and dominates the skyline from Bellingham to Vancouver, British Columbia. The next eruption of Mount Baker may produce lava flows, pyroclastic flows, volcanic ash (tephra), and lahars. Lahars are by far the greatest concern at Mount Baker because of its history of frequent lahars, the ability of lahars to flow for tens of miles, and the potential for hazardous future impacts of lahars on two reservoirs on the east side of the volcano. "Tephra hazards at Mount Baker are less important than at neighboring Glacier Peak."[120] About 6,000 years ago Mount Baker had a tephra producing event in which a large collapse of the Roman Wall transformed into a lahar that was over 300 feet deep in the upper reaches of the Middle Fork of the Nooksack River (Figure 19-14). It was at least 25 feet deep more than 30 miles downstream from the volcano and most likely reached Bellingham Bay.

Figure 19-14 Deposit from the Largest Lahar from Mount Baker. Wall exposed near the confluence of the middle and North Forks of the Nooksack River, about 20 miles from its source at the Roman Wall. Note the protruding logs and branches from living trees that were knocked down and carried by the lahar. Ice axe, 3 ft. shows scale.

A large hydrovolcanic explosion formed the present shape of Sherman Crater on Mount Baker in 1843. Rivers south of the volcano were clogged with ash. A short time later, two collapses of the east side of Sherman Crater produced two lahars: the first and larger of which flowed into the natural Baker Lake, raising its level at least 10 feet. The location of this 19th Century lake is now covered by waters of the modern dam impounded Baker Lake.

Similar but lower levels of hydrovolcanic activity at Sherman Crater continued intermittently for several decades after this event. In 1891, about 20 million cubic yards of rock fell from Mount Baker's Sherman Crater, producing a lahar that traveled more than 6 miles and covered 1 square mile with mud and debris. In March of 1975, gas and steam emission and heat flow rates increased significantly. The activity gradually declined over the next 2 years but stabilized at a much higher rate than before the 1975 event. Several small lahars formed from materials ejected onto the surrounding glaciers and acidic water was discharged into Baker Lake for many months. Due to this event, U.S. Geological Survey (USGS) scientists embarked on the most intensive monitoring applied to a Cascade volcano up until that time to determine if the recent events were signs of more violent activity to come. "As time passed, no signs of rising magma - earthquakes, significant changes in gas composition, or surface deformation – appeared." The main risk was therefore determined to be flank collapses and lahars similar to those experienced in 1843.

The formation of a lahar is the greatest potential hazard from Mount Rainier. From Mount Rainier, lahars have traveled at a rate of 45-50 miles per hour with depths of over 100 feet where confined in valleys near the volcano, slowing and thinning in the wide and now populated valley floors below. Lahars are a greater hazard than any other volcanic product such as lava flows or pyroclastic flows, because lava flows and pyroclastic flows from this volcano are unlikely to extend more than a few miles beyond the boundaries of Mount Rainier National Park. Volcanic ash (tephra) will be distributed downwind 80 percent of the time toward the east away from the large populations of the greater Puget Sound region.[121]

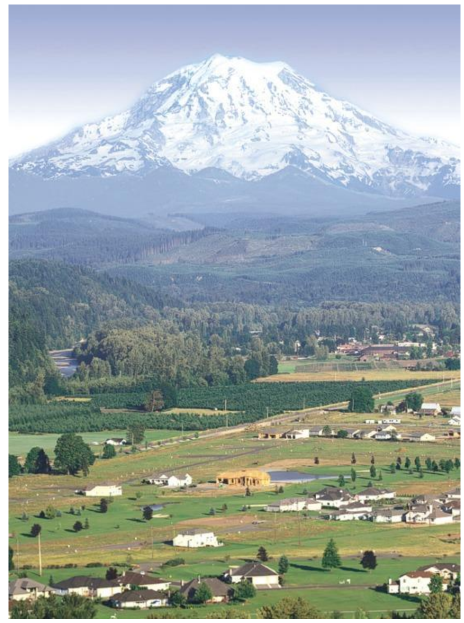


Figure 19-15 Mount Rainier across the Puyallup River Valley

Although Mount Rainer has erupted less often and less explosively than its neighbor Mount St. Helens, the large populations near the volcano make it a far greater hazard to life and property. More than 150,000 people live on the deposits of previous lahars, with more people moving to these locations every year (Figure 19-15). During the past several thousand years, lahars that have reached the Puget Sound lowlands have occurred on average every 500 to 1,000 years. Smaller lahars with flows not reaching as far as the lowland area occur more frequently.

If future lahars happen at the same rates seen in the past, there is at least a one in ten chance of a lahar reaching the Puget Sound lowland during an average human life span. Future lahars will follow river valleys that drain the volcano of which four of the five river systems flow westward into suburban areas of Pierce County, Washington. A lahar during an eruption may affect valley areas miles away from Mount Rainier but a precursory warning that the volcano is moving toward eruption should allow ample time for evacuation by those affected. A catastrophic lahar flow will likely spread into multiple valleys. The largest known from Mount Rainier entered all five drainages and most other known flows have entered two or more river valleys.

USGS research shows that some lahars from Mount Rainier can occur with little or no warning. The estimated minimum time between detection of a lahar and its arrival in the city of Orting is about 40 minutes. Populations dispersed closer to the volcano can be affected sooner. Because of the high level of risk from lahars in the Carbon and Puyallup River valleys, the USGS, Pierce County Department of Emergency Management, and the Washington State Emergency Management Division have installed a lahar-detection and warning system. The system consists of arrays of monitors that detect the ground vibrations of a lahar. Computerized evaluation of data confirms the presence of a flowing lahar and issues an automatic alert to the State Emergency Operations Center located at Camp Murray and the Law Enforcement Support Agency in Tacoma. Emergency managers can then initiate response measures such as evacuations and warnings to the affected areas and jurisdictions.

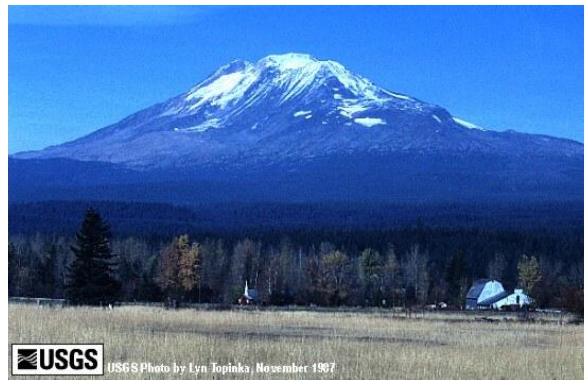


Figure 19-16 Mount Adams

Mount Adams (Figure 19-16), one of the largest volcanoes in the Cascade Range, dominates the Mount Adams volcanic field located in Skamania, Klickitat, and Lewis Counties in addition to the Yakama Indian Reservation of South-Central Washington. During much of this volcano's history, it has displayed a relatively limited range of eruptive styles with highly explosive eruptions being a rarity. Despite the uncommonness of eruptions at this volcano, when an eruption does happen, it could be very hazardous. Large landslides and lahars pose the most destructive and far-reaching hazard from this volcano.[122] More importantly, even during times of no eruptive activity, landslides of weakened rock that originate on the steep upper flanks of Mount Adams can spawn lahars which can devastate valley floors miles away from the volcano. The steep upper slopes of Mount Adams have produced several notable debris avalanches. In 1921, about 5 million cubic yards of altered rock fell from the head of Avalanche Glacier (Figure 19-17) on the southwest flank of the volcano and travelled almost 4 miles down into Salt Creek

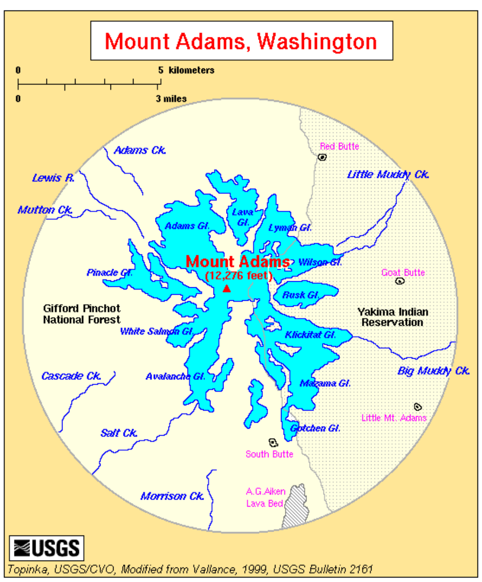


Figure 19-17 Location of Glaciers on Mount Adams

Valley. This debris avalanche contained or acquired enough water to partly transform into small lahars.

Ancient debris avalanches of much larger size than this have occurred at Mount Adams, with lahars forming from these travelling as far down as the Columbia River. Remains of one of the largest lahars, about 6,000 years ago, from Mount Adams can be seen today as a sediment layer in the banks of the White Salmon River and as isolated blocks that protrude from fields and meadows in the Trout Lake lowland. Lahars that occur either from eruptions or debris avalanches at Mount Adams affect downstream channels and provide a source of easily eroded sediment. The resulting channels become unstable and have the potential to shift. Channel capacity also shrinks increasing the risks for flooding. Streams that drain the north and northwest flanks of Mount Adams can discharge sediment from lahars into Swift Reservoir on the Lewis River and Riffe Lake on the Cowlitz River. Streams that drain the southwest and east flank of the volcano can deliver sediment and debris from lahars into the Columbia River and could affect navigation and hydroelectric operations at Bonneville Dam. Impacts on the small reservoir and hydroelectric operation on the White Salmon River could be severe.

Mount St. Helens has been the most active volcano in our State during the past few thousand years. In addition to its well-known eruption in May of 1980, this volcano has undergone many stages of unrest and ongoing eruptions, including the ongoing eruption currently taking place that started in September of 2004 and ended in early 2008.

Mount St. Helens has produced lava flows, lava domes, deposits of ash, pyroclastic flows, landslides, and lahars. Although it is notorious for the event of May 18, 1980, which included a gigantic landslide and explosion, smaller events at this volcano are also potentially dangerous.

Legislation passed by the United States Congress in 1974 established the USGS as the lead agency in charge of providing reliable and timely warnings of volcanic hazards to State and local authorities. Under this Congressional mandate, following the Mount St. Helens eruption of May 1980, the USGS established the Cascades Volcano Observatory, a permanent regional office located in Vancouver, Washington. "Observatory scientists, technicians, and support staff work in partnership with colleagues at other USGS centers, universities, and other agencies to monitor restless volcanoes and provide timely warning of eruptions, assess hazards from volcanoes, including water-related hazards in valleys draining volcanoes, share volcano information with emergency management and planning officials, develop new techniques and methods to better monitor and predict behavior of volcanoes, study volcanic processes, and educate public officials, citizens, and the news media."[123]

The National Volcano Early Warning System (NVEWS) is a proposed national-scale effort by the USGS Volcano Hazards Program and other affiliated partners to ensure that volcanoes are monitored at a level commensurate with the threat that they pose. Of the Washington State volcanoes that were identified by the framework's assessment, four (Rainier, Glacier Peak, Baker, St. Helens) received a highest priority and one (Adams) received a high priority. This framework seeks to establish enhanced instrumentation and monitoring at targeted volcanoes and a continuously manned volcano watch office to improve the ability to provide rapid, reliable hazard warnings. Efforts by the Pierce County Department of Emergency Management and the USGS to install a lahar warning system along the Puyallup and Carbon River for Mount Rainier lahar hazards is a step in the right direction for establishing early warning systems for Washington's volcanoes.

To keep the people, the economy, the environment, and property of Washington safe, it is essential to monitor hazardous volcanoes and prepare for the hazards that may result from volcanic activity. With help from the USGS, the public, policy makers, and state and local emergency managers can make informed decisions how to best prepare for and react to volcano hazards in the state and reduce losses from future volcanic eruptions, lahars, and or volcanic ash fall incidents.

Internet Resources

United States Geological Survey, Cascades Volcano Observatory
http://vulcan.wr.usgs.gov/

Volcano Hazards Program of the U.S. Geological Survey
http://volcanoes.usgs.gov/

Pacific Northwest Seismic Network, Volcano Seismicity
http://www.pnsn.org/INFO_GENERAL/volcanoes.html

National Volcano Early Warning System, U.S. Geological Survey
http://pubs.usgs.gov/of/2005/1164/

U.S. Geological Survey Fact Sheets
http://water.usgs.gov/wid/index-hazards.html

Washington Volcanic Ash Advisory Center (Mt. St. Helens)
http://www.ssd.noaa.gov/VAA/hele.html

APPENDIX A – Hazards Found in County Plans

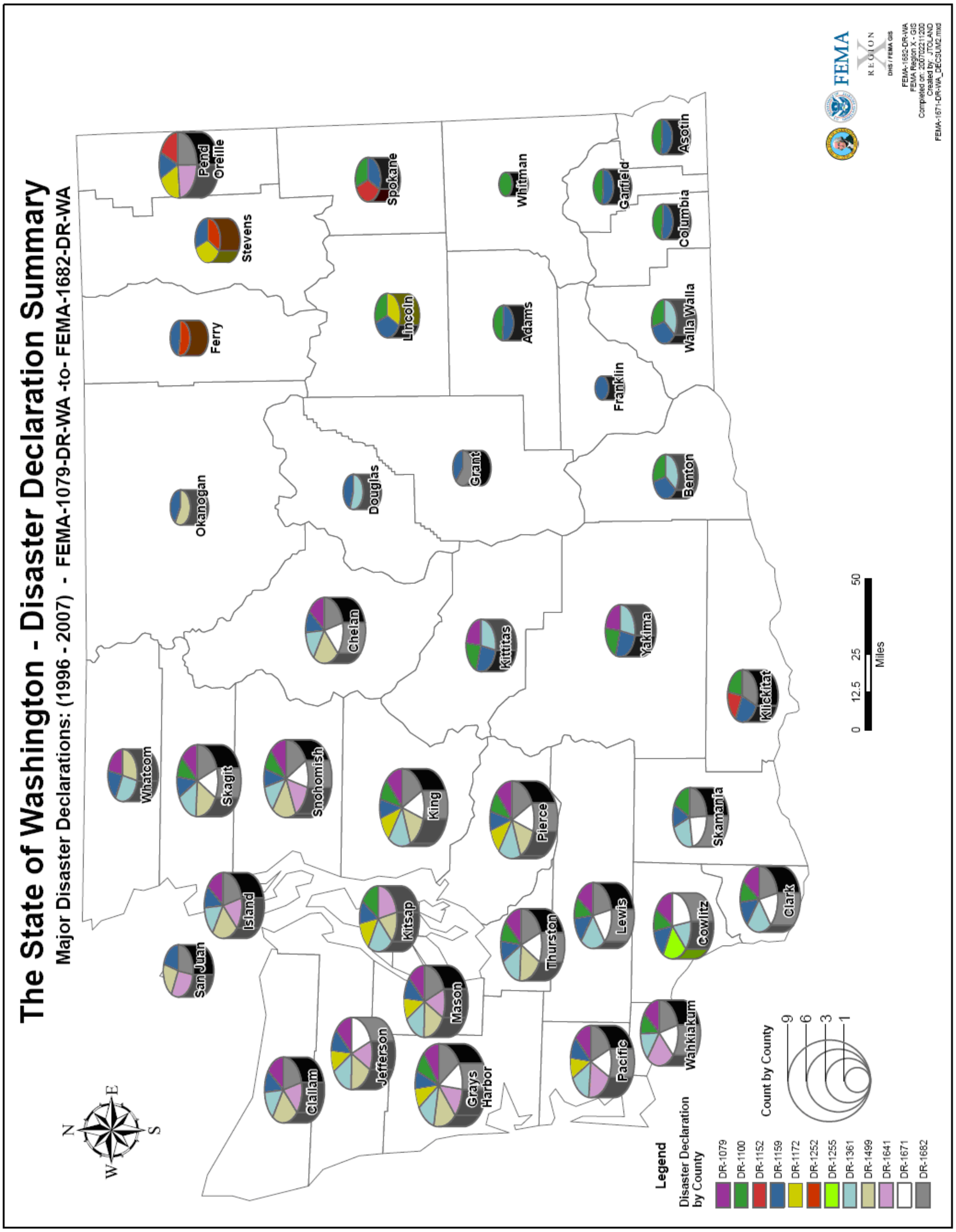
	COUNTY																																						
HAZARDS	Adams	Asotin	Benton	Chelan	Clallam	Clark	Columbia	Cowlitz	Douglas	Ferry	Franklin	Garfield	Grant	Grays Harbor	Island	Jefferson	King	Kitsap	Kittitas	Klickitat	Lewis	Lincoln	Mason	Okanogan	Pacific	Pend Oreille	Pierce	San Juan	Skagit	Skamania	Snohomish	Spokane	Stevens	Thurston	Wahkiakum	Walla Walla	Whatcom	Whitman	Yakima
Abandoned Underground Mine		X																	X							X	X						X						
Airplane Crash						X																																	
Military Aviation Accident															X																					X			
Avalanche																X	X									X	X		X				X				X		X
Chemical	X	X								X		X			X							X										X						X	
Chemical Spills							X																																
Civil Disorder																		X								X	X												
Civil Disturbance	X	X	X	X					X	X	X	X	X		X	X			X			X	X	X		X	X					X	X	X		X		X	
Civil Unrest																																							X
Columbia Generating Station			X																																				
Hanford Site													X																										
Dam Failure	X	X	X	X		X			X			X			X	X		X	X	X		X	X	X	X	X	X	X		X		X	X	X	X	X		X	X
Columbia River Dam Failure																																				X			
Mill Creek Dam Failure																																				X			
Snake River Dam Failure																																				X			
Crime											X																												
Workplace Violence																																							X
Disease/Epidemic																																					X		
Epidemic	X																						X				X						X	X					X
Infestation Disease							X				X		X																										
Drought	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X		X	X	X	X	X		X	X	X			X	X	X
Water Shortage																																							X
Earthquake	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Seismic (Earthquake & Tsunami)					X																																		
Economical Crisis											X																												X
Fire																													X						X				X
Conflagration																					X																		
Fire Hazards																	X																						
Firestorm																					X																		
Forest Fire																										X							X						
Forest Fire/Wildfire																							X																
Forest Fire/Wildland Fire																																					X		
Forest/Wildfire																																							
Forest/Wildland Fire						X																																	
Major Wildland Fire										X			X																										
Wildfire							X	X									X	X		X									X		X					X			X
Wildfire/Forest Fire																																		X					
Wildland Fire	X	X	X	X						X		X	X	X					X		X	X		X	X	X		X				X	X					X	
Forest-Urban Interface Fire																		X																					
Urban-Wildland Interface Fire																				X							X												
Urban/Wildland Fire					X																																		
Wildland Interface Fire															X																								
Wildland- Urban Interface Fire													X								X																		
Wildland/Forest/Interface Fires																X																							
Major Urban Fire											X		X																										
Urban Conflagration																																				X			
Urban Fire	X	X	X	X				X			X	X			X	X	X		X			X		X		X						X	X					X	
Flood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Flash Flooding																																				X			
River Flooding																																				X			
River Flooding & Channel Migration					X																																		
Riverine & Coastal Processes (Channel Migration)							X																																
Tidal Overflow/ Coastal Flooding																		X																			X		
Hazardous Materials	X	X	X	X		X			X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X		X	X	X	X	X	X	X			X	X
Hazardous Site/Materials																		X										X								X			X
Key Employer Crisis								X			X																												

Continued on next page

COUNTY

HAZARDS	Adams	Asotin	Benton	Chelan	Clallam	Clark	Columbia	Cowlitz	Douglas	Ferry	Franklin	Garfield	Grant	Grays Harbor	Island	Jefferson	King	Kitsap	Kittitas	Klickitat	Lewis	Lincoln	Mason	Okanogan	Pacific	Pend Oreille	Pierce	San Juan	Skagit	Skamania	Snohomish	Spokane	Stevens	Thurston	Wahkiakum	Walla Walla	Whatcom	Whitman	Yakima
Land Movement (Landslide, Debris/Mudflow)													■																■										
Landslide		■	■		■	■			■	■		■		■	■	■	■				■	■				■	■			■		■	■	■	■		■		■
Landslide & Erosion								■			■																												
Slides (Avalanche & Landslide)																			■					■															
Subsidence/ Expansive Soils											■																												
Local Hazard										■	■	■	■									■										■						■	
Special Hazards													■																										
Mass Casualty											■		■							■													■						
Nuclear Incidents																							■																
Nuclear Detonation																																	■						
Radiation Incident	■	■	■								■				■																								
Radiological							■		■	■		■	■					■		■		■				■		■				■				■		■	■
Pipeline										■					■							■	■				■					■						■	
Search & Rescue Emergency		■																■		■					■	■							■						■
Severe Storm				■	■		■	■	■																														
Hail				■	■	■					■		■										■																
Heat Waves											■												■											■					■
High Winds													■										■											■					
Ice, Snow, & Windstorms																																							■
Lightning					■						■		■																■										
Severe Cold	■																																						
Severe Local Storm	■	■				■				■		■				■						■			■	■			■	■		■	■						
Severe Storm/Winter																								■															
Severe Weather																	■	■																					
Severe Winter Storm											■		■																										
Shelter/Refuge Site																■																							
Snowstorm																■																			■				
Storm																							■											■					■
Tornado	■					■								■												■				■			■		■	■			■
Windstorms			■	■							■		■	■																									
Winter Storm	■																								■							■						■
Terrorism	■	■	■						■	■	■	■			■	■	■		■	■		■	■	■	■		■	■			■	■	■	■		■		■	■
Cybertoerrorism																	■																						
Food & Water Contamination																■																							
Terrorism & Violent Persons						■																				■				■			■						
Terrorism/Civil Disorder																		■																					
Terrorism/Sabotage				■																																			
Weapons of Mass Destruction																																							
Transportation	■	■	■		■				■	■		■	■		■		■					■						■				■						■	
Transportation Accidents																											■								■				■
Transportation/ Mass Casualty																		■																					
Tsunami														■	■	■									■			■						■			■		
Tsnuami/Seishe								■									■	■									■		■		■								
Tsunami/High Waves/Seishes																							■																
Umatilla Chemical Depot			■																																				
Chemical Weapons																																				■			
Utility Outage				■									■						■					■															
Communications													■																										
Critical Shortage	■																									■							■	■					
Energy Emergency						■										■		■		■				■		■	■			■			■						■
Loss of Electrical Service	■	■								■	■		■																										
Loss of Gas Service											■		■																										
Loss of Sewer Service											■		■																										
Loss of Water Service											■		■																										
Power Outage	■	■	■						■																										■				■
Telecommunications Failure											■																												
Utilities & Communications					■																																		
Volcano	■	■	■	■		■		■	■	■		■			■	■			■			■		■		■				■	■	■	■	■			■	■	■
Volcanic Activity											■		■							■	■																		
Volcanic Eruption																																			■				
Volcanic Event																												■											
Volcanic Hazards																										■													
Volcano/Ash Fall							■							■				■					■												■			

APPENDIX B – Past Presidential Declarations



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APPENDIX C – Glossary

AEGL ....Acute Exposure Guideline Levels
AFM ....Acoustic flow monitor
ANSS............Advanced national Seismic System
APA..............Areas of Planning Attention
BPA...............Bonneville Power Administration
CEMP...........Comprehensive Emergency Management Plan
CFR...............Council on Foreign Relations
CGS...............Columbia Generating Station
CMA.............Chemical Materials Agency
CNCI ....Comprehensive National Cyber Initiative
CNSS ....Council of the National Seismic System
CSEPP ....Chemical Stockpile Emergency Preparedness Program
CSZ...............Cascadia Subduction Zone
CVO..............Cascades Volcano Observatory
D2-Puff™......Plume dispersion model customized for the CSEPP Program
DART ....Deep-ocean Assessment and Reporting of Tsunamis
DHHS...........Department of Health and Human Services
DHS..............Department of Homeland Security
DOE..............Department of Energy
EAS...............Emergency Alert System
ELF ....Earth Liberation Front
EMD ....Emergency Management Division
EPA...............Environmental Protection Agency
EPCRA..........Emergency Planning and Community Right to Know Act of 1986
EPZ...............Emergency Planning Zone
FBI.................Federal Bureau of Investigation
FEMA...........Federal Emergency Management Agency
GDP..............Gross Domestic Product
GIS................Geographic Information System
HIVA.............Hazard Identification and Vulnerability Assessment
HSIP ....Homeland Security Infrastructure Protection
IEM...............Innovative Emergency Management
IFFRCPP ....Integrated Fixed Facility Radiological and Chemical Protection Plan
INRTTF ....Inland Northwest Regional Terrorism Task Force
MODIS..........Moderate Resolution Imaging Spectroradiometer
NDCD ....National Climatic Data Center

Glossary – Cont.

NEHRP ....National Earthquake Hazards Reduction Program
NEPA ....National Environmental Policy Act
NFIP ....National Flood Insurance Program
NOAA...........National Oceanic and Atmospheric Administration
NRC...............U.S. Nuclear Regulatory Commission
NCMC...........Nation Drought Mitigation Center
NTHMP ....National Tsunami Hazard Mitigation Program
NVEWS.........National Volcano Early Warning System
NWAC ....Northwest Weather and Avalanche Center
NWCC...........Northwest Interagency Coordination Center
NWCCTF......Northwest Cyber Crime Task Force
NWCG ....National Wildfire Coordinating Group
NWS ....National Weather Service
OPCW ....Organization for the Prohibition of Chemical Weapons
PNSN ....Pacific Northwest Seismic Network
PNW..............Pacific Northwest
PNWCG........Pacific Northwest Wildfire Coordinating Group
PSCTWG.......Puget Sound Counterterrorism Working Group
PSJTTF...........Puget Sound Joint Terrorism Task Force
RCW ....Revised Code of Washington
RSAC.............Remotes Sensing Applications Center
SAL................State Agency Liaison
SBCCOM ......U.S. Army Soldier Biological and Chemical Command
SDP ....State Domestic Product
UMCD...........Umatilla Chemical Depot
USC ...............U.S. Code
USDA ............U.S. Department of Agriculture
USGS .............U.S. Geological Survey
UTC ....Washington Utilities and Transportation Commission
VHP ....Volcano Hazard Plan
WAC..............Washington Administrative Code
WADNR ....Washington Department of Natural Resources
WebPuff™ ....Internet-based plume dispersion model replacing D2-Puff
WMD.............Weapon of mass destruction
WSDOT.........Washington State Department of Transportation

APPENDIX D – Figures

(Citations are formatted as per the Gregg Reference Manual, 9th Edition)

Fig. A Table, "Washington Disaster History – Major Disaster Declarations," *Federal Emergency Management Agency*, n.d., <http://www.fema.gov/news/disasters_state.fema?id=53> (November 16, 2007).

Fig. B "Homeland Security Working Group Symbology Reference," *Federal Geographic Data Committee*, September 14, 2005, <http://www.fgdc.gov/HSWG/index.html> (November 16, 2007).

Avalanche

1-1 Map, Allen Jakobitz, "Washington State Avalanche Hazard Areas," *Washington Emergency Management Division*, October 14, 2007.

1-2 Illustration, "Ingredients for a Slab Avalanche," *Northwest Weather and Avalanche Center*, n.d., <http://www.nwac.us/reference/slab_graphic.htm> (November 16, 2007).

1-3 Graph, "Avalanche Fatalities by State 1950-2006," *Colorado Avalanche Information Center*, n.d, <http://avalanche.state.co.us/Accidents/Statistics/> (November 16, 2007).

1-4 Photo, George Plafker, "Aerial Photo of 1970 Yungay, Peru Avalanche," *U.S. Geological Survey*, 1970.

1-5 Photo, "WSDOT Crews Use explosives on Chinook Pass to trigger an avalanche," *WA State Dept. of Transportation*, 2007, <http://www.wsdot.wa.gov/Traffic/Passes/Chinook/2007photos.htm> (November 16, 2007).

1-6 Photo, "I-90 Snow Shed on Snoqualmie Pass," *WA State Dept. of Transportation*, n.d., <http://hrc.leg.wa.gov/Warnick/newsroom/enewsletters/070323.htm> (December 4, 2008).

Columbia Generating Station

2-1 Map, Kelly Cassidy, "Washington Rage Map – Burrowing Owls," *Bird Web – Seattle Audubon Society*, 2003, <http://www.birdweb.org/birdweb/bird_details.aspx?value=search&id=247#wa_map> (November 29, 2008).

2-2 Map, "10-Mile Emergency Planning Zone," *WA State Emergency Management Division*, June 2007, < http://emd.wa.gov/telcom/images/10-mi-epz.jpg> (December 4, 2008).

2-3 Photo, "Columbia Generating Station," *Energy Northwest*, n.d., <http://www.energy-northwest.com/generation/cgs/index.php> (October 20, 2008).

2-4 Table, "List of minor incidents that have occurred at CGS in recent history", Washington State Emergency Management Division, April 10, 2009

2-5 Map, "50-Mile Emergency Planning Zone," *WA State Emergency Management Division*, June 2007, < http://emd.wa.gov/telcom/images/50-mi-epz.jpg> (December 4, 2008).

2-6 Map, “Map of the United States Showing Locations of Operating Nuclear Power Reactors,” *U.S. Nuclear Regulatory Commission*, n.d., <http://www.nrc.gov/info-finder/reactor/> (October 8, 2008).

Dam Failure/Levee Break

3-1 Map, Cathy Walker, “Low, Significant, and high Hazard Dams in Washington,” *WA Military Department – GIS Section,* September 10, 2008.

3-2 Photo, “Aerial View of Flooded Residential Area,” *WA State Dept. of Ecology*, October 1991, <http://www.ecy.wa.gov/programs/wr/dams/seminary.html> (September 10, 2008).

3-3 Photo, Library of Congress, “Club House Press Looking South – 1889,” *Suburban Emergency Management Project*, May 11, 2006, <http://www.semp.us/publications/biot_reader.php?BiotID=359> (September 10, 2008).

3-4 Chart, “Jurisdiction of Dams in Washington,” *WA State Dept. of Ecology – Dam Safety Guidelines*, September 2004, <http://www.ecy.wa.gov/pubs/9255a.pdf> (September 10, 2008).

3-5 Chart, “Types of Dams under Ecology Jurisdiction,” *WA State Dept. of Ecology – Dam Safety Guidelines*, September 2004, <http://www.ecy.wa.gov/pubs/9255a.pdf> (September 10, 2008).

3-6 Chart, “Number of Dams by Height/Hazard,” *WA State Dept. of Ecology – Dam Safety Guidelines*, September 2004, <http://www.ecy.wa.gov/pubs/9255a.pdf> (September 10, 2008).

Drought

4-1 Map, Cathy Walker, “Drought Susceptibility for Washington State 2001-2007,” *WA State Military Department – GIS Section*, March 17, 2008.

4-2 Photo, “Lake Roosevelt in Stevens County,” *WA State Dept. of Ecology*, April 25, 2005, <http://www.ecy.wa.gov/programs/WR/ws/drtphoto.html> (February 22, 2008).

4-3 Map, “Drought Monitor Archives”, *National Drought Mitigation Center – University of Nebraska-Lincoln,* n.d., <http://www.drought.unl.edu/dm/archive.html> (February 22, 2008).

4-4 Map, “Palmer Drought Severity Index 1988 and 1989,” *National Drought Mitigation Center – University of Nebraska-Lincoln,* n.d., <http://www.drought.unl.edu/whatis/palmer/pdi88.gif> (February 25, 2008).

4-5 Map, “Palmer Drought Severity Index 1930-1939,” *National Drought Mitigation Center – University of Nebraska-Lincoln*, n.d., <http://www.drought.unl.edu/whatis/palmer/pdi3039.gif> (February 25, 2008).

4-6 Graph, “Monthly Precipitation of the PNW for 1990-1998,” *Climate Impacts Group – University of Washington*, n.d., <http://cses.washington.edu/cig/pnwc/pnwc.shtml> (March 21, 2008).

4-7 Graph, “Various Indicators of Drought,” *U.S. Geological Survey*, Open File Report 93-642, April 2001, http://pubs.usgs.gov/of/ 1993/ofr93-642/pdf/ofr93-642.pdf> (February 19, 2008).

Earthquake

5-1 Map, U.S. Geological Survey, National Seismic Mapping Project 2008," *Peak Acceleration (% gravity (g)) with 2% Probability of Exceedance in 50 Years"* http://earthquake.usgs.gov/regional/states/washington /hazards.php (May 4, 2009)

5-2 Illustration, "Strike-slip and Dip-Slip Faults," *Rapid Earthquake Viewer*, n.d., <http://rev.seis.sc.edu/ definition.html> (November 16, 2007).

5-3 Table, "Earthquakes – The Modified Mercalli Scale and the Richter Scale," *Federal Emergency Management Agency*, n.d., <http://www.fema.gov/kids/intense.htm> (November 16, 2007).

5-4 Table, "Largest Earthquakes in the United States," *U.S. Geological Survey*, June 7, 2005, <http://earthquake.usgs.gov/regional/states/10_largest_us.php> (November 16, 2007).

Epidemic/Pandemic

6-1 Map, Cathy Walker, "Estimates of Washington State Population by County as of April 2008," *WA State Military Department – GIS Section*, September 22, 2008.

6-2 Table, "Mortality Statistics 1918 – Table 1," Department of Commerce, Bureau of the Census, 1920, *Centers for Disease Control and Prevention*, n.d., <http://cdc.gov/nchs/data/vsushistorical/ mortstatsh_1918.pdf> (September 22, 2008).

6-3 Table, "Pandemics Death Toll Since 1900," *PandemicFlu.gov*, n.d., <http://www.pandemicflu.gov/ general> (August 25, 2008).

6-4 Map, "Nations with Confirmed Cases of A/H1N1 Swine Flu Virus", *World Health Organization (WHO)*, < http://www.who.int/csr/don/2009_06_29/en/index.html> (June 29, 2009).

6-5 Illustration, "Global Environmental Change," *World Health Organization*, n.d., <http://www.who.int/ globalchange/en/index.html> (August 25, 2008).

6-6 Table, WA State Dept. of Health, "Influenza and Pneumonia Deaths in 1918 by Age," September 10, 2008, e-mail correspondence.

Fire, Urban

7-1 Map, Cathy Walker, "2008 Urban Fires in Washington State by Fire Region," *WA State Military Department – GIS Section*, September 1, 2009.

7-2 Illustration, "Washington State Fire Clock," *WA State Patrol – Fire Marshal's Office*, April 1, 2009, <http://www.wsp.wa.gov/fire/docs/nfirs/2008firpt.pdf> (September 1, 2009).

7-3 Table, "Summary of 2006 Incident Type Categories," *WA State Patrol – Fire Marshal's Office*, April 1, 2009, <http://www.wsp.wa.gov/fire/docs/nfirs/2008firpt.pdf> (September 1, 2009).

7-4 Table, “Places Fire Fatalities Occurred in Washington in 2008”, *WA State Patrol – Fire Marshal’s Office*, April 1, 2009, <http://www.wsp.wa.gov/fire/docs/nfirs/2008firpt.pdf> (September 1, 2009).

7-5 Illustration, “Residential Properties Area of Origin,” *WA State Patrol – Fire Marshal’s Office*, June 1, 2007, <http://www.wsp.wa.gov/fire/docs/nfirs/2006firpt.pdf> (December 17, 2007).

Fire, Wildland

8-1 Map, Washington Department of Natural Resources, “Wildland-Urban Interface Communities at Risk for Fire,” September 18, 2007 <http://www.dnr.wa.gov/Publications/rp_burn_communitiesatrisk.pdf> September 1, 2009.

8-2 Photo, “Tree Line Wildland Fire,” *National Park Service*, n.d., <http://www.nps.gov/fire/fire/fir_wildland.cfm> (February 29, 2008).

8-3 Map, “Significant Fire Potential Map,” *National Interagency Fire Center and Geographic Area Coordination Centers – Predictive Services Program,* < http://svinetfc6.fs.fed.us/NPSG/staticmap.html> (November 25, 2008).

8-4 Photo, Jim McVeigh, “Harris Fire Lights Up Otay Lakes,” *The San Diego Wildfires Education Project*, October 23, 2007, <http://interwork.sdsu.edu/fire/photo_gallery/2007_fires/harris-fire.html> (February 29, 2008).

8-5 Table, “Annual Fire Report – Pacific Northwest Area 2006,” *Northwest Interagency Coordination Center*, 2006, <http://www.nwccweb.us/content/products/Intelligence/AnnualFireReport.pdf> (December 31, 2007).

8-6 Graph, A. L. Westerling, et al., “Western US Forest Wildfires and Spring-Summer Temperature,” *Science Magazine*, August 18, 2006, Vol. 313, No. 5879, pp. 940-943, <http://www.sciencemag.org/cgi/content/full/313/5789/940#REF26> (February 29, 2008).

Flood

9-1 Map, Cathy Walker, “Washington State Governor’s Proclamations Due to Flooding 1997-2007,” *WA State Military Department – GIS Section*, July 16, 2008.

9-2 Map, “Presidential Disaster Declarations Related to Flooding in the United States and Puerto Rico,” *U.S. Geological Survey*, Fact Sheet 2006-3026, January 2006, <http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf> (June 5, 2008).

9-3 Map, “Total Number of Policies in Force,” *National Flood Insurance Program*, September 30, 2007, <http://www.fema.gov/library/viewRecord.do?id=3172> (July 22, 2008).

9-4 Chart, Lindsay Mangum, “Main Contributors to Rising Sea Levels,” *National Public Radio*, January 14, 2008, <http://www.npr.org/templates/story/story.php?storyId=18022014> (July 22, 2008).

9-5 Graph, Lindsay Mangum, “Global Ocean Temperature Change Since 1900,” *National Public Radio*, January 14, 2008, <http://www.npr.org/templates/story/story.php?storyId=18022014> (July 22, 2008).

Incident, Chemical

10-1 Map, Cathy Walker, “Washington State chemical Manufacturers and Department of Ecology Permitted Facilities,” *WA State Military Department – GIS Section*, March 24, 2008.

10-2 Photo, Bettmann/Corbis, “Train Derailment near Milligan, Florida,” *Pollution Issues*, n.d., <http://www.pollutionissues.com/Co-Ea/Disasters-Chemical-Accidents-and-Spills.html> (May 27, 2008).

10-3 Illustration, “Department of Transportation Placards,” *Florida Atlantic University*, n.d., <http://www.fau.edu/divdept/envhs/DOT.html> (May 30, 2008).

10-4 Graph, “Ecology Meth Labs and Dumps,” *WA State Dept. of Ecology*, Publication 07-08-001, January 2008, <http://www.ecy.wa.gov/pubs/0708001.pdf> (April 10, 2008).

Incident, Radiological

11-1 Map, Cathy Walker, “Population Density and Potential Locations of Radiological Material,” *WA State Military Department – GIS Section*, October 30, 2008.

11-2 Illustration, “Five Types of Ionizing Radiation,” *U.S. Nuclear Regulatory Commission*, n.d., <http://www.nrc.gov/about-nrc/radiation/health-effects/radiation-basics.html> (October 29, 2008).

11-3 Table, “Measuring Radiation’s Effects,” *U.S. Nuclear Regulatory Commission*, n.d., <http://www.nrc.gov/about-nrc/radiation/rad-health-effects.html> (October 29, 2008).

Infestation

12-1 Map, Cathy Walker, “Insect and Disease Detection of Forested Acres in Washington 1997-2007,” *WA State Military Department – GIS Section*, September 30, 2008.

12-2 Photo, “Mountain Pine Beetle Infestation in Canadian Forest,” *Natural Resources Canada*, September 1, 2006, <http://canadaforests.nrcan.gc.ca/articletopic/8> (September 30, 2008).

12-3 Map, “Total Area Affected by Mountain Pine Beetle in Western Canada,” *Natural Resources Canada*, February 2006, <http://canadaforests.nrcan.gc.ca/articletopic/8> (September 30, 2008).

12-4 Map, Cathy Walker, “Locations of National Forests, Parks, and Recreation Areas within Washington State,” *WA State Military Department – GIS Section*, September 30, 2008.

Landslide

13-1 Map, Cathy Walker, “Landslide Hazards in Washington State,” *WA State Military Department – GIS Section*, January 17, 2008.

13-2 Illustration, “How Deep-Seated Slides Work,” *WA State Dept. of Ecology*, n.d., <http://www.ecy.wa.gov/programs/sea/landslides/about/deep.html> (January 15, 2008).

13-3 Illustration, “How Shallow Slides Work,” *WA State Dept. of Ecology*, n.d., <http://www.ecy.wa.gov/programs/sea/landslides/about/shallow.html> (January 15, 2008).

13-4 Illustration, “How Bench Slides Work,” *WA State Dept. of Ecology*, n.d., <http://www.ecy.wa.gov/programs/sea/landslides/about/bench.html> (January 15, 2008).

13-5 Illustration, “How Large Slides Work,” *WA State Dept. of Ecology*, n.d., <http://www.ecy.wa.gov/programs/sea/landslides/about/slump.html> (January 15, 2008).

13-6 Photo, T. Tamura, “Oblique Aerial View of the Landslide at Rolling Bay Walk,” Seattle Times, 1996, *U.S. Geological Survey*, 1998, <http://pubs.usgs.gov/of/1998/ofr-98-239/figure2.html> (January 15, 2008).

13-7 Photo, “The 1983 Thistle Landslide, Central Utah,” *U.S. Geological Survey*, Open File Report 01-0276, 2001, <http://pubs.usgs.gov/of/2001/ofr-01-0276/> (January 15, 2008).

Pipelines

14-1 Map, Cathy Walker, “Washington State Pipeline Distribution Network,” *WA State Military Department – GIS Section*, October 7, 2008.

14-2 Photo, Kerwin Plevka, “A Lyondell Petrochemical Co. Pipeline Explodes as the San Jacinto River Floods,” *Houston Chronicle*, October 1994, <http://blogs.chron.com/sciguy/archives/2008/05/> (October 9, 2008).

14-3 Graphs, “National, All Pipeline Systems, Significant Incidents,” *U.S. Dept. of Transportation, Pipeline and Hazardous Materials Safety Administration – Office of Pipeline Safety* October 14, 2008, <http://primis.phmsa.dot.gov/comm/reports/safety/SigPSI.html> (October 13, 2008).

Severe Storm

15-1 Map, Cathy Walker, “Severe Storm Elements in Washington 1997-2007,” *WA State Military Department – GIS Section*, August 14, 2008.

15-2 Photo, Oregonlive.com, “Effects of the December 2006 Western Washington Windstorm,” *Peninsula Emergency Preparedness Committee*, n.d., <http://www.pep-c.org/windstorms/> (August 14, 2008).

15-3 Map, “Super-outbreak of Tornados April 3-4, 1974,” *Storm Prediction Center – National Oceanic and Atmospheric Administration*, May 26, 2008, <http://www.spc.noaa.gov/faq/tornado/apr03_74.gif> (August 14, 2008).

Terrorism

16-1 Map, Cathy Walker, “Population Density of Washington State Counties,” *WA State Military Department – GIS Section*, October 20, 2008.

16-2 Photo, Mary Levin, University of Washington, “The University of Washington Center for urban Horticulture in 2001, after the Arson,” *Crosscut*, May 30, 2008, <http://crosscut.com/2008/05/30/crime-safety/14655/> (October 20, 2008).

Tsunami

17-1 Map, Cathy Walker, “Tsunami Inundation Map for Washington State,” *WA State Military Department – GIS Section*, February 13, 2008.

17-2 Illustration, “Regular Wind-generated Waves vs. Tsunami Waves,” *NASA Observatorium*, n.d., <http://physics.ship.edu/~mrc/astro/NASA_Space_Science/observe.arc.nasa.gov/nasa/exhibits/tsunami/tsun_physics.html>

17-3 Photo, “May 1964 Tsunami Damage Near Kodiak, Alaska,” *National Oceanic and Atmospheric Association – National Weather Service*, Handout, n.d., <http://www.stormready.noaa.gov/resources/Storm&TsunamiReadyHandout.pdf> (February 12, 2008).

17-4 Illustration, “Tsunami hazards for the West Coast of the United States,” *National Oceanic and Atmospheric Administration – Pacific Marine Environmental Laboratory*, March 31, 1995, <http://nthmp-history.pmel.noaa.gov/senatec.pdf> (February 12, 2008).

17-5 Photo, “First Operation DART Buoy System,” *NOAA Center for Tsunami Research*, n.d., <http://nctr.pmel.noaa.gov/Dart/index.html> (February 12, 2008).

17-6 Map, “DART Locations March 2008,” *NOAA Center for Tsunami Research*, n.d., <http://nctr.pmel.noaa.gov/Dart/index.html> (February 12, 2008).

17-7 Illustrations, “Tsunami Evacuation Route and Tsunami Hazard Zone Signs,” *WA State Dept. of Transportation*, n.d., <http://wsdot.wa.gov/biz/trafficoperations/traffic/newsigns.htm> (February 13, 2008).

17-8 Logo, “TsunamiReady™ National Weather Service Logo,” *TsunamiReady-National Oceanic and Atmospheric Administration*, n.d., <http://www.tsunamiready.noaa.gov/> (February 13, 2008).

17-9 Map, “Washington 7 TsunamiReady Sites,” *TsunamiReady-National Oceanic and Atmospheric Administration*, n.d., <http://www.tsunamiready.noaa.gov/ts-com/wa-ts.htm> (February 13, 2008).

Umatilla Chemical Depot

18-1 Map, Allen Jakobitz, “Umatilla Chemical Depot Emergency Zones,” *Washington Emergency Management Division*, November 20, 2007.

18-2 Photo, “Umatilla Chemical Depot Entrance,” *Benton County Emergency Services*, n.d., <http://www.bces.wa.gov/front%20gate.jpg> (November 20, 2007).

18-3 Photo, “155mm Projectile,” *Kentucky Division of Emergency Management*, n.d., <http://kyem.ky.gov/NR/rdonlyres/710C8FB0-9F90-47B3-AC79-C05F87341290/0/155mmProjectile.jpg> (November 20, 2007).

18-4 Photo, “M55 Rocket,” *Kentucky Division of Emergency Management*, n.d., <http://kyem.ky.gov/NR/rdonlyres/65867260-E68F-458B-AE43-DE6B167596AB/0/115mmRocketcopy.jpg> (November 20, 2007).

18-5 Photo, “Storage Igloo,” *Kentucky Division of Emergency Management*, n.d., <http://kyem.ky.gov/NR/rdonlyres/9110B225-2C7F-4464-9269-0A53C84F9906/0/IglooSideView.jpg> (November 20, 2007).

18-6 Photo, “Umatilla Chemical Agent Disposal Facility,” *Global Security*, n.d. <http://www.globalsecurity.org/wmd/facility/images/umatilla-SITE101.jpg> (November 20, 2007).

18-7 Photo, “Outdoor Warning Siren,” *Chemical Stockpile Emergency Preparedness Program*, n.d., <http://csepp.net/warnmain.html> (November 20, 2007).

18-8 Photo, “Tone Alert Radio,” *Chemical Stockpile Emergency Preparedness Program*, n.d., <http://csepp.net/warnmain.html> (November 20, 2007).

18-9 Photo, “Highway Message Reader Board,” *Chemical Stockpile Emergency Preparedness Program*, n.d., <http://csepp.net/warnmain.html> (November 20, 2007).

18-10 Screenshot, “WebPuff™ Screenshot,” *WebPuff* (inaccessible without login ID.), <https://george.emd.wa.gov/WebPuff3.1/home.do> (November 20, 2007).

Volcano

19-1 Map, Cathy Walker, “Volcano Locations in Washington State,” *WA State Military Department – GIS Section*, November 16, 2007.

19-2 Map, R.B. Waitt, et al., “Areas at Risk from Lahars, Lava Domes, Pyroclastic Flows, and Associated Phenomena from Glacier Peak,” *U.S. Geological Survey*, Fact Sheet 058-00, 1995, <http://pubs.usgs.gov/fs/2000/fs058-00/> (November 14, 2007).

19-3 Map, “Hazard Zones for Lahars, Pyroclastic Flows, and Lava Flows,” *U.S. Geological Survey*, Fact Sheet 059-00, 2000, <http://pubs.usgs.gov/ fs/2000/fs059-00/> (November 14, 2007).

19-4 Map, Scott, William E., Iverson, Richard M., Vallance, James W., and Hildreth, Wes, “Volcano-Hazard-Zonation Map of Mount Adams, Washington”, USGS Open File Report 95-497, *http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/*, 1995.

19-5 Map, “Hazard Zones for Debris Flows, Lahars, Lava Flows, and Pyroclastic Flows from Mount Rainier,” *U.S. Geological Survey*, Fact Sheet 2008-3062, 2008, <http://pubs.usgs.gov/fs/2008/3062/fs2008-3062.pdf> (December 1, 2008).

19-6 Map, Wolfe, Edward W. and Pierson, Thomas, C., “Volcanic-Hazard Zonation for Mount St. Helens,” USGS Open File Report 95-497, http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/framework.html , 1995.

19-7 Map, “Annual Probability of Tephra Fall …Glacier Peak,” *U.S. Geological Survey*, Fact Sheet 058-00, 1995, <http://pubs.usgs.gov/ fs/2000/fs058-00/> (November 14, 2007).

19-8 Map, “Annual Probability of Volcanic Ash…Mount Rainer,” *U.S. Geological Survey*, Fact Sheet 034-02, 2002, <http://pubs.usgs.gov/ fs/2002/fs034-02/> (November 14, 2007).

19-9 Map, “Annual Probability of Tephra…Cascade Volcanoes,” *U.S. Geological Survey*, Open File Report 95-492, 1995, <http://vulcan.wr.usgs.gov/Volcanoes/Adams/Hazards/OFR95-492/OFR95-492.pdf> (November 14, 2007).

19-10 Map, Scott et al., “Annual Probability of Tephra…Pacific Northwest Volcanoes,” *U.S. Geological Survey*, Open File Report 95-492, 1995, <http://vulcan.wr.usgs.gov/Volcanoes/Cascades/Hazards/ash_accumulation_10cm.html> (November 14, 2007).

19-11 Photo, Harry Glicken, “Mount St. Helens May 18, 1980 Debris Avalanche,” *U.S. Geological Survey*, May 18, 1980, <http://vulcan.wr.usgs.gov/Volcanoes/MSH/Images/MSH80/may18_devastation.html> (October 31, 2007).

19-12 Photo, R.B. Waitt, “Lahar Deposit by Prehistoric Eruptions,” *U.S. Geological Survey*, Fact Sheet 058-00, 2000, <http://pubs.usgs.gov/fs/2000/fs058-00/> (October 31, 2007).

19-13 Map, “Total Thickness of Tephra…Glacier Peak,” *U.S. Geological Survey*, Fact Sheet 058-00, 2000, <http://pubs.usgs.gov/fs/2000/fs058-00/> (October 31, 2007).

19-14 Photo, Kevin Scott, “Deposit of Largest Lahar from Mount Baker,” *U.S. Geological Survey*, Fact Sheet 059-00, 2000, <http://pubs.usgs.gov/fs/2000/fs059-00/> (October 31, 2007).

19-15 Photo, D.E. Wieprecht, “Mount Rainier Across the Puyallup River Valley,” *U.S. Geological Survey*, Fact Sheet 2008-3062, 2008, <http://pubs.usgs.gov/fs/2002/3062/> (November 14, 2007).

19-16 Photo, Lyn Topinka, “Mount Adams as seen from Trout Lake,” *U.S. Geological Survey*, November 5, 1987, <http://vulcan.wr.usgs.gov/Volcanoes/Adams/images.html> (November 16, 2007).

19-17 Map, “Mount Adams Glaciers,” *U.S. Geological Survey*, 1999, <http://vulcan.wr.usgs.gov/Volcanoes/Adams/Maps/map_adams.html> (November 16, 2007).

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APPENDIX E – Citations

(Citations are formatted as per the Gregg Reference Manual, 9th Edition)

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[1] “RCW 38.52.080,” *WA State Legislature*, 1995, <http://apps.leg.wa.gov/RCW/default.aspx?cite=38.52.030> (December 5, 2008).

[2] “44 CFR Ch. 1, Part 206 - Federal Disaster Assistance for Disasters Declared On or After November 23, 1988,” *U.S. Government Printing Office*, n.d., <http://www.access.gpo.gov/nara/cfr/waisidx_02/44cfr206_02.html> (December 11, 2007).

Avalanche

[3] Mark Moore, “Avalanche Glossary,” *Northwest Weather and Avalanche Center*, September 27, 2008, <http://www.nwac.us/education_resources/Avalanche_Glossary.htm> (October 9, 2007).

[4] “Glossary of Terms in Ecology and Restoration.” *National Park Service – Plant Conservation Alliance's Restoration Working Group*, n.d., <http://www.nps.gov/plants/restore/library/glossary.htm> (October 5, 2007).

[5] “Avalanche Accident Statistics,” *Colorado Avalanche Information Center*, n.d., <http://avalanche.state.co.us/Accidents/Statistics/> (October 4, 2007).

[6] “Avalanches: Case Studies,” *Forces of Nature*, n.d., <http://library.thinkquest.org/C003603/english/index.shtml> (October 9, 2007).

[7] “Avalanche Control,” *Washington State Department of Transportation*, n.d., <http://www.wsdot.wa.gov/maintenance/avalanche/> (October 5, 2007).

[8] As per maintenance staff member, *Washington State Dept. of Transportation – North Central Office*, October 9, 2007.

[9] “I-90 Snoqualmie Pass East – Hyak to Keechelus Dam,” *Washington State Department of Transportation*, n.d., <http://www.wsdot.wa.gov/projects/i90/snoqualmiepasseast/hyaktokeechelusdam/> (October 3, 2008).

[10] Robin McKie, “Decades of Devastation Ahead as Global Warming Melts the Alps,” *People and Planet*, July 23, 2003, <http://www.peopleandplanet.net/doc.php?id=2026> (October 9, 2007).

Columbia Generating Station

[11] “Hanford Site Virtual Tours – Energy Northwest,” *DOE Hanford Site*, December 12, 2006, <http://hanford.gov/?page=338&parent=326> (January 24, 2008).

[12] “Columbia Generating Station,” *Benton County Emergency Services*, n.d., <http:www.bces.wa.gov/columbia_generating_station.htm> (October 28, 2008).

[13] “Emergency Preparedness for Nuclear Facilities in Washington State,” *WA State Dept. of Agriculture*, December 2007, <http://www.agr.wa.gov/FoodSecurity/Attachments/Trifold07.pdf> (November 13, 2008).

[14] CGS Boiling Water Reactor,” *U.S. Nuclear Regulatory Commission*, n.d., <http:www.nrc.gov/info-finder/reactor/wash2.html> (February 14, 2008).

[15] “How We Respond to an Emergency,” *U.S. Nuclear Regulatory Commission*, n.d., <http://www.nrc.gov/about-nrc/emerg-preparedness/respond-to-emergency.html> (August 13, 2008).

Dam Failure/Levee Break

[16] "Notable Dam Failures," *WA State Dept. of Ecology – Dam Safety Office*, n.d., <http://www.ecy.wa.gov/ programs/wr/dams/failure.html> (September 10, 2008).

[17] Connie Clarke, "The Johnstown Flood: The Worst Dam Failure in U.S. History," *ABC News*, March 2, 2007, Online, <http://abcnews.go.com/print?id=2918360> (September 18, 2008).

[18] Johnson, Doug. Washington State Department of Ecology – Dam Safety Office. E-mail correspondence. 27 May 2009.

[19] Jim Salter, "Army Corps Says Condition of Many Levees a Mystery," *Omaha World Herald*, May 12, 2008, <http://www.omaha.com/index.php?u_page=1100&u_sid=10333001> (November 19, 2008).

Drought

[20] "Washington State Hazard Mitigation Plan," *WA State Military Dept. – Emergency Management Division*, January 28, 2008, <http://www.emd.wa.gov/plans/washington_state_hazard_mitigation_plan.shtml> (November 18, 2008)

[21] "2005 Drought Response – Report to the Legislature," *WA State Dept. of Ecology*, Pub. No. 06-11-001, February 2006, <http://www.ecy.wa.gov/pubs/0611001.pdf> (November 13, 2008).

[22] Joe A. Moreland, "Drought," *U.S. Geological Survey*, Open File Report 93-642, April 2001, <http://pubs.er.usgs.gov/ usgspubs/ ofr/ofr93642> (February 19, 2008).

[23] "Hazard Identification and Vulnerability Assessment (HIVA)," *WA State Military Dept. – Emergency Management Division*, 2001, <http://www.emd.wa.gov/plans/documents/hazard_identification_vulnerability_analysis.doc>

[24] "2001 Drought Response – Report to the Legislature," *WA State Dept. of Ecology*, Pub. No. 01-11-017, December 2001, <http://www.ecy.wa.gov/pubs/0111017.pdf> (November 13, 2008).

[25] "2001 Drought Response – Report to the Legislature," *WA State Dept. of Ecology*, Pub. No. 01-11-017, December 2001, <http://www.ecy.wa.gov/pubs/0111017.pdf> (November 13, 2008).

[26] "Drought," *NOAA – National Weather Service*, Public Fact Sheet, January 2008. <http://www.weather.gov/os/ brochures/climate/Drought2.pdf > (February 25, 2008).

[27] "Drought in the Dust Bowl Years," *National Drought Mitigation Center – University of Nebraska-Lincoln*, 2006, <http://www.drought.unl.edu/ whatis/dustbowl.htm> (October 13, 2008).

[28] "About Pacific Northwest Climate," *Climate Impacts Group – University of Washington*, n.d. <http://cses.washington.edu/cig/pnwc/pnwc.shtml> (February 20, 2008).

[29] "Climate Impacts on Pacific Northwest Water Resources," *Climate Impacts Group – University of Washington*, n.d., <http://www.cses.washington.edu/cig/pnwc/pnwwater.shtml> (February 20, 2008).

[30] "Drought and Climate Change," *National Drought Mitigation Center – University of Nebraska-Lincoln*, 2006, <http://www.rought.unl.edu/risk/Impactvulnerability.htm> (February 20, 2008).

[31] "Predicting Drought," *National Drought Mitigation Center – University of Nebraska-Lincoln*, 2006, <http://www.drought.unl.edu/whatis/predict.htm> (October 13, 2008).

[32] "Planning for Drought," *National Drought Mitigation Center – University of Nebraska-Lincoln*, 2006, <http://www.drought.unl.edu/risk/impactvulnerability.htm> (March 21, 2008).

Earthquake

[33] "Washington State Hazard Mitigation Plan," *WA State Military Dept. – Emergency Management Division*, January 28, 2008, <http://www.emd.wa.gov/plans/washington_state_hazard_mitigation_plan.shtml> (November 18, 2008)

Epidemic/Pandemic

[34] Eric Alzar, "Open Remarks – Washington State Summit," *Deputy Secretary of Health and Human Services*, April 14, 2006, <http://pandemicflu.gov/general/greatpandemic3.html#washington> (August 25, 2008).

[35] "The Great Pandemic – The United States in 1918-1919: Washington State," *1918 Pandemic Flu*, U.S. Dept. of Health and Human Services, n.d., <http://1918.pandemicflu.gov/your_state/washington.htm> (November 12, 2008).

[36] "Pandemic Influenza," *Global Security*, n.d., <http://www.globalsecurity.org/security/ops/hsc-scen-3_pandemic-influenza.htm> (August 27, 2008).

[37] Center for Disease Control (CDC), "Novel H1N1 Flu Situation Update – June 26, 2009", *FluView*, <http://www.cdc.gov/h1n1flu/update.htm>. (June 29, 2009).

[38] "Climate Change and Human Health," *World Health Organization*, n.d., <http://www.who.int/globalchange/climate/en/index.html> (August 25, 2008).

[39] "A Message from Governor Chris Gregoire: Preparing for Pandemic Influenza – A Washington State Overview 2006," *WA State Department of Health*, DOH Publication 820-028, March 2006 <http://www.doh.wa.gov/ panflu/planning_summary/pandemic_overview_smr.pdf> (June 26, 2008).

Fire, Urban

[40] "Urban Fire – Multiple Units," *Boulder County Office of Emergency Management*, 2000, <http://www.co.boulder.co.us/sheriff/pdf/oem/urban_fire.pdf> (December 17, 2007).

[41] "Fire in the United States 1995-2004," *U.S. Fire Administration*, 14th Edition, August 2007, < http://www.usfa.dhs.gov/downloads/pdf/publications/fa-311.pdf> (December 17, 2007).

[42] "2008 Fire in Washington," *Washington State Patrol – Office of the State Fire Marshal*, June 2006, <http://www.wsp.wa.gov/fire/docs/nfirs/2006firpt.pdf> (December 12, 2007).

[43] "Working Together for Home Fire Safety," *U.S. Fire Administration*, March 2006, <http://www.usfa.dhs.gov/downloads/pdf/fswy11.pdf> (December 31, 2007).

[44] "Glossary of Wildland Fire Terminology," *National Wildfire Coordinating Group*, n.d., <http://www.nwcg.gov/pms/pubs/glossary/index.htm> (December 20, 2007).

[45] "Fire Information," *WA Dept. of Natural Resources*, n.d., <http://www.dnr.wa.gov/RecreationEducation/Topics/FireInformation/Pages/rp_fire_fireinformation.aspx> (December 20, 2007).

[46] "About Spokane District," *U.S. Dept. of the Interior Bureau of Land Management*, n.d., <http://www.blm.gov/or/districts/spokane/about.php> (December 31, 2007).

[47] "Worst U.S. Forest Fires," *Pearson Education - InfoPlease*, n.d., <http://www.infoplease.com/ipa/A0778688.html> (December 17, 2007).

[48] "Annual Fire Report – Pacific Northwest Area 2006," *Northwest Interagency Coordination Center*, 2006, <http://www.nwccweb.us/content/products/Intelligence/AnnualFireReport.pdf> (December 31, 2007).

[49] Steve Running, "Is Global Warming Causing More, Larger Wildfires?" *Science Magazine*, Online July 6, 2006, Vol. 313, No. 5789, pp. 927-928, (December 17, 2007).

[50] "Wildfire Hazards – A National Threat," *U.S. Geological Survey*, Fact Sheet 2006-3015, February 2006, <http://pubs.usgs.gov/fs/ 2006/3015> (December 28, 2007).

Floods

[51] Jim E. O'Conner and John E. Costa, "Large Floods in the United States: Where They Happen and Why," *U.S. Geological Survey*, Circular 1245, 2003 <http://pubs.usgs.gov/circ/2003/circ1245> (June 25, 2008).

[52] "Flood Hazards – A National Threat," *U.S. Geological Survey*, Fact Sheet 2006-3026, January 2006, <http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf> (June 24, 2008).

[53] "Resources: Flood Facts," *National Flood Insurance Program – Flood Smart*, n.d., <http://www.floodsmart.gov/floodsmart/pages/flood_facts.jsp> (July 22, 2008).

[54] Gerald E. Galloway, "A Flood of Unheeded Warnings," *The Washington Post*, June 25, 2008, p. A13, <http://www.washingtonpost.com/wp-dyn/content/article/2008/06/24/AR2008062401213.html> (June 26, 2008).

[55] Frances Stead Sellers, "Changing Course to Go with the Flow," *The Washington Post*, September 11, 2005, p. B03, <http://www.washingtonpost.com/wp-dyn/content/article/2005/09/09/AR2005090902425.html> (June 26, 2008).

[56] "The World's Worst Floods by Death Toll," *Epic Disasters*, n.d., <http://www.epicdisasters.com/index.php/site/comments/the_worlds_worst_floods_by_death_toll/> (July 15, 2008).

[57] "The National Flood Insurance Program Community Status Book," *Federal Emergency Management Agency*, June 14, 2007, <http://www.fema.gov/fema/csb.shtm> (July 22, 2008).

[58] P. C. D. Milly, R. T. Wetherald, K. A. Dunne, and T. L. Delworth, "Increasing Risk of Great Floods in a Changing Climate," *Nature Magazine*, January 31, 2002, Vol. 415, pp. 514-517, <http://www.nature.com/nature/journal/v415/n6871/full/415514a.html> (June 26, 2008).

[59] Hillary Mayell, "Climate Studies Point to More Floods in This Century," *National Geographic*, January 30, 2002 <http://news.nationalgeographic.com/news/2002/01/0130_020130_greatfloods.html> (July 22, 2008).

[60] Anna Vigran, "With Climate Change Comes Floods," *National Public Radio*, Online January 14, 2008, <http://www.npr.org/templates/story/story.php?storyId=18022014> (July 22, 2008).

[61] Patrick McCully, "New Thinking Needed on Floods," *The Baltimore Sun*, July 17, 2007, p. 11A (June 26, 2008).

[62] "Resources: Frequently Asked Questions," *National Flood Insurance Program – Flood Smart*, n.d., <http://www.floodsmart.gov/floodsmart/pages/faqs_flood.jsp> (July 25, 2008).

Incident, Chemical

[63] Richard J. Watts and Patricia Hemminger, "Disasters: Chemical Accidents and Spills," *Pollution Issues*, n.d., <http://www.pollutionissues.com/Co-Ea/Disasters-Chemical-Accidents-and-Spills.html> (May 27, 2008).

[64] "National Situation Update: Tuesday, February 13, 2007," *Federal Emergency Management Agency*, February 13, 2007, <http://www.fema.gov/emergency/reports/2007/nat021307.shtm> (May 27, 2008).

[65] Susan Gordon, "Thousands Could Have Been Exposed to Deadly Gas on Tacoma's Tideflats," *The Tacoma News Tribune*, March 9, 2008, Available <http://forums.firehouse.com/showthread.php?t=99140> (May 28, 2008).

[66] Dale Jensen, "Spill Prevention, Preparedness & Response Program," *WA State Dept. of Ecology*, Publication 07-01-35, September 2007, <http://www.ecy.wa.gov/programs/spills/other/overbook_spills.pdf> (April 10, 2008).

[67] Steve Hunter, "Meth Lab Incident Report by County – December," *WA State Dept. of Ecology*, Publication 07-08-001, February 2007, <http://www.ecy.wa.gov/pubs/0708001.pdf> (April 10, 2008).

Incident, Radiological

[68] "Fact Sheet on the Accident at the Chernobyl Nuclear Power Plant," *U.S. Nuclear Regulatory Commission*, December 2000, <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fschernobyl.html> (November 3, 2008).

[69] "Fact Sheet on the Three Mile Island Accident," *U.S. Nuclear Regulatory Commission*, February 2007, <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html> (November 3, 2008).

[70] "Integrated Fixed Facility Radiological and Chemical Protection Plan," *WA State Emergency Management Division*, 2008 <http://www.emd.wa.gov/plans/documents/IFFRCPPMarch2008.pdf> (November 6, 2008).

[71] "Radioactive Materials Section," *WA State Dept. of Health*, n.d., <http://www.doh.wa.gov/ehp/rp/materials/rmhome.htm> (November 6, 2008).

Infestation

[72] D. Pimentel, L. Lach, R. Zuniga, and D. Morrison, "Environmental and Economic Costs of Nonindigenous Species in the United States," *BioScience*, January 2000, Vol. 50, No. 1, pp. 53-54 <http://www.jstor.org/pss/1313688> (November 12, 2008).

[73] David Dunn and James P. Crutchfield, "Entomogenic Climate Change," *University of California Davis*, May 25, 2008. <http://cse.ucdavis.edu/~chaos/papers/ecc.pdf> (September 30, 2008).

[74] Robin J. Tausch, "Invasive Plants and Climate Change," *U.S. Forest Service*, 2008, <http://www.fs.fed.us/ccrc/topics/invasive-plants.shtml> (October 1, 2008).

Landslides

[75] Jonathan Godt, "Landslide Overview Map of the Conterminous United States," *U.S. Geological Survey*, Open File Report 97-289, 1997, <http://landslides.usgs.gov/learning/nationalmap/> (January 17, 2008).

[76] "Landslides 101," *U.S. Geological Survey*, n.d., <http://landslides.usgs.gov/learning/ls101.php> (January 14, 2008).

[77] "Definition of Landslide". *The American Heritage Dictionary of the English Language*, Fourth Edition, 2000, <http://www.bartleby.com/61/83/L0038300.html> (January 22, 2008).

[78] "About Slides on Puget Sound," *WA State Dept. of Ecology*, n.d., <http://www.ecy.wa.gov/programs/sea/landslides/about/about.html> (January 15, 2008).

[79] "Landslide Types and Processes," *U.S. Geological Survey*, Fact Sheet 2004-3072, July 2004, <http://pubs.usgs.gov/fs/2004/3072/pdf/fs2004-3072.pdf> (January 15, 2008).

[80] Edwin L. Harp, John A. Michael, and William T. Laprade, "Shallow-Landslide Hazard Map of Seattle, Washington," *U.S. Geological Survey*, Open-File Report 2006-1139, 2006, <http://pubs.usgs.gov/of/2006/1139/pdf/of06-139_508.pdf> (January 22, 2008).

[81] "Frequently Asked Questions," *U.S. Geological Survey*, n.d., <http://landslides.usgs.gov/learning/faq/> (January 24, 2008).

[82] Robert Roy Britt, "Surprising Side Effects of Global Warming," *LiveScience*, December 22, 2004, <http://www.livescience.com/environment/041222_permafrost.html> (January 25, 2008).

[83] Alister Doyle, "Landslide Could Worsen with Global Warming – UN," *Planet Ark*. January 18, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/34540/story.htm> (January 25, 2008).

Pipelines

[84] "Glossary of Climate Change Terms," *U.S. Environmental Protection Agency*, n.d., <http://www.epa.gov/climatechange/glossary.html#N> (October 9, 2008).

[85] "Energy Conversion Factors – Definitions," *Oregon Dept. of Energy*, n.d., <http://www.oregon.gov/ENERGY/CONS/Industry/Definitions.shtml#Crude_Oil> (October 9, 2008).

[86] "Oil & Gas Glossary: Chemical Terms," *Seisma Oil Research*, n.d., <http://www.seismaresearch.com/glossary/chemical4.html> (October 9, 2008).

Severe Storm

[87] Tom Ross and Neal Lott, "Billion Dollar U.S. Weather Disasters," *National Climatic Data Center*, n.d., <http://www.ncdc.noaa.gov/oa/reports/billionz.html#TOP> (August 21, 2008).

[88] "WA State Hazard Mitigation Plan; Hazard Profile – Severe Storm," *WA State Emergency Management Division*, January 28, 2008, <http://emd.wa.gov/plans/washington_state_hazard_mitigation_plan.shtml> (August 21, 2008).

[89] "Climate Change Scenarios," *Climate Impacts Group*, n.d., <http://cses.washington.edu/cig/fpt/ccscenarios.shtml> (August 21, 2008).

Terrorism

[90] "Terrorism –Counterterrorism Definitions and Policies," *Federal Bureau of Investigation – Denver, CO*, n.d., <http://denver.fbi.gov/nfip.htm> (October 15, 2008).

[91] Dorothy Denning, "Cyberterrorism," *Georgetown University*, May 23, 2000, <http://cs.georgetown.edu/~denning/infosec/cyberterror.html> (October 17, 2008).

[92] "Weapons of Mass Destruction," *Federal Bureau of Investigation*, n.d., <http://www.fbi.gov/hq/nsb/wmd/wmd_home.htm> (December 4, 2008).

[93] Hal Bernton, Mike Carter, David Heath, and James Neff, "The Terrorist Within: The Story Behind One Man's Holy War Against America – Chapter 14: Puzzle Pieces," *The Seattle Times*, July 7, 2002, <http://seattletimes.nwsource.com/news/nation-world/terroristwithin/chapter15.html> (October 16, 2008).

[94] Valerie Easton, "ELF Members Gained Nothing By the UW Arson, and so much was Lost," *Crosscut*, May 30, 2008, <http://crosscut.com/2008/05/30/crime-safety/14655/> (October 20, 2008).

[95] Graham T. Allison, Online Debate, "How Likely is a Nuclear Terrorist Attack on the United States?" April 13-20, 2007, <http://www.cfr.org/publication/13097/how_likely_is_a_nuclear_terrorist_attack_on_the_united_states.html> (December 4, 2008).

[96] Gabriel Weimann, "Cyberterrorism: How Real is the Threat?" *U.S. Institute of Peace*, December 2004, Special Report No. 119, <http://www.usip.org/pubs/specialreports/sr119.html> (October 27, 2008).

[97] Robert D. Jamison, "Our Newest Cyber Threat," *U.S. Dept. of Homeland Security*, September 20, 2008, <http://www.dhs.gov/journal/leadership/2008/09/our-newest-cyber-threat.html> (October 15, 2008).

Tsunami

[98] Nathan Wood and Christopher Soulard, "Variations in Community Exposure and Sensitivity to Tsunami Hazards on the Open-Ocean and Strait of Juan de Fuca Coasts of Washington," *U.S. Geological Survey*, January 9, 2008, <http://pubs.usgs.gov/sir/2008/5004/> (March 5, 2008).

[99] "Potential Ecological Impacts of Indian Ocean Tsunami on Nearshore Marine Ecosystems," *NOAA News Online*, Story 2362, n.d., <http://www.noaanews.noaa.gov/stories2005/s2362.htm> (February 5, 2008).

[100] "Tsunamis," *WA State Dept. of Natural Resources*, n.d., <http://www.dnr.wa.gov/ResearchScience/Topics/GeologicHazardsMapping/Pages/tsunamis.aspx> (February 12, 2008).

[101] "Local Tsunamis in the Pacific Northwest," *U.S. Geological Survey – Western Coastal & Marine Geology*, n.d., <http://walrus.wr.usgs.gov/tsunami/cascadia.html> (February 13, 2008).

[102] "Frequently Asked Questions," *National Oceanic and Atmospheric Association – NWS/West Coast and Alaska Tsunami Warning Center*, May 2006, <http://wcatwc.arh.noaa.gov/faq/frequently.php> (February 1, 2008).

[103] "Tsunami Event – Indonesia, December 26, 2004," *National Oceanic and Atmospheric Association – National Geophysical Data Center*, n.d., <http://www.ngdc.noaa.gov/nndc/struts /results?EQ_0=2439&t=101650&s =9&d=100,91,95,93&nd=display> (February 4, 2008).

[104] "Tsunami Hazard Mitigation Plan – A Report to the Senate Appropriations Committee," *National Oceanic and Atmospheric Association – Pacific Marine Environmental Laboratory*, April 1996, <http://nthmp-history.pmel.noaa.gov/hazard3.pdf> (February 12, 2008).

[105] "Tsunami Hazards – A National Threat," *U.S. Geological Survey*, Fact Sheet 2006-3023, February 2006, <http://pubs.usgs.gov/fs/2006/3023/2006-3023.pdf> (February 2, 2008).

[106] "About DART® Tsunami Monitoring Buoys," *National Oceanic and Atmospheric Association Center for Tsunami Research*, n.d., <http://nctr.pmel.noaa.gov/Dart/about-dart.html> (December 4, 2008).

[107] "Tsunami Evacuation Route and Tsunami Hazard Zone Signs," *WA State Dept. of Transportation*, n.d., <http://wsdot.wa.gov/biz/trafficoperations/traffic/newsigns.htm> (February 13, 2008).

[108] "Is Your Community Ready for a Natural Disaster?" *National Oceanic and Atmospheric Association – National Weather Service*, Handout, n.d., <http://www.stormready.noaa.gov/resources/Storm&TsunamiReadyHandout.pdf> (February 13, 2008).

Umatilla Chemical Depot

[109] "Article II. Definitions and Criteria," *OPCW – Chemical Weapons Convention*, September 27, 2005, <http://www.opcw.org/chemical-weapons-convention/articles/article-ii-definitions-and-criteria/> (November 20, 2007).

[110] "Yesterday and Today – A Brief History of the U.S. Army Umatilla Chemical Depot," *Chemical Stockpile Emergency Preparedness Program*, September 18, 2007, <http://www.csepp.net/frfactsheets.html> (November 20, 2007).

[111] "Army Destroys Last Nerve agent Munition in Oregon Chemical Weapons Stockpile". *Umatilla Chemical Depot, Press Release*. November 5, 2008. < http://www.cma.army.mil/fndocumentviewer.aspx?docid=003679396> (May 15, 2009)

[112] Daniel R. Civis, "The United States Chemical Stockpile Emergency Preparedness Program: A Framework for Community Preparedness," *Defence Science and Technology Library (UK)*, 2006, <http://www.dstl.gov.uk/ conferences/cwd/2006/civis.pdf> (November 13, 2008).

Volcano

[113] "VHP Photo Glossary: Volcano," *U.S. Geological Survey – Volcano Hazards Program*, n.d., <http://volcanoes.usgs.gov/images/pglossary/volcano.php> (November 2007).

[114] "VHP Photo Glossary: Lahar," *U.S. Geological Survey – Volcano Hazards Program*, n.d., <http://volcanoes.usgs.gov/ images/pglossary/lahar.php> (November 2007).

[115] "Pyroclastic," *Webster's II New College Dictionary*, 2nd Edition, 1999.

[116] C. A. Kenedi, S. R. Brantley, J. W. Hendley II, and P. H. Stauffer, "Volcanic Ash Fall – A 'Hard Rain' of Abrasive Particles," *U.S. Geological Survey*, Fact Sheet 027-00, 2000, <http://pubs.usgs.gov/fs/fs027-00/ fs027-00.pdf> (November 13, 2008).

[117] Steve R. Brantley and Bobbie Myers, "Mount St. Helens – From the 1980 Eruption to 2000," *U.S. Geological Survey*, March 2000, <http://pubs.usgs.gov/fs/2000/fs036-00/fs036-00.pdf> (November 13, 2008).

[118] Dan Dzurisin, Peter H. Stauffer, and James W. Hendley II, "Living with volcanic Risk in the Cascades," *U.S. Geological Survey*, Fact Sheet 165-97, March 2008, <http://pubs.usgs.gov/fs/1997/fs165-97/fs165-97.pdf> (November 13, 2008).

[119] Larry Mastin, and Richard Waitt, "Glacier Peak – History and Hazards of a cascade Volcano", *U.S. Geological Survey*, Fact Sheet 058-00, 2000, <http://pubs.usgs.gov/fs/2000/fs058-00/> (November 13, 2008).

[120] Kevin M. Scott, Wes Hildreth, and Cynthia A. Gardner, "Mount Baker – Living with an Active Volcano," *U.S. Geological Survey*, Fact Sheet 059-00, May 2000, <http://pubs.usgs.gov/fs/2000/fs059-00/fs059-00.pdf> (November 13, 2008).

[121] Carolyn L. Driedger and William E. Scott, "Mount Rainier – Living Safely with a Volcano in Your Backyard," *U.S. Geological Survey*, Fact Sheet 2008-3062, 2008, <http://pubs.usgs.gov/fs/2008/3062/fs2008-3062.pdf> (November 13, 2008).

[122] William E. Scott, Richard M. Iverson, James W. Vallance, and Wes Hildreth, "Volcano Hazards in the Mount Adams Region, Washington," *U.S. Geological Survey*, Open File Report 95-492, 1995, <http://vulcan.wr.usgs.gov/Volcanoes/Adams/Hazards/OFR95-492/OFR95-492.pdf> (November 13, 2008).

[123] "Who's Keeping Watch Over Cascades Volcanoes?" *U.S. Geological Survey*, Open File Report 97-125, 1997, <http://vulcan.wr.usgs.gov/Volcanoes/Cascades/Publications/OFR97-125/OFR97-125.html> (November 19, 2007).

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